A Harmonic Development of the Tide-Generating Potential

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Abstract

Harmonic development of the tide-generating potential is numerically made with the MERIT standards and the JPL ephemerides. The expansion is made up to the 4th order potential for Moon and the 3rd one for Sun, and the secular variation of harmonic amplitude is also taken into account for the period between 1950 and 2030. All tidal constituents, whose amplitudes (in Doodson's scale) are larger than 10×10^{-6} for the 2nd order potential, 7×10^{-6} for the 3rd one and 5×10^{-6} for the 4th one, are picked up. These amplitude thresholds are correspond to 1n*Gal* for each constituent.

1. Introduction

Recent earth tide observations, such as gravity tide ones with superconductivity gravity meter or null method LaCoste G meter, have high precision and stability. These observations give us precious informations of earth's interior. In order to obtain much more knowledge of the earth, not only precise and intense observations but precise analysis methods are required.

It is needless to say that the precise theoretical tide calculation is needed in tidal analysis and prediction. Several authors (Doodson, 1921, 1954), (Cartwright and Tayler, 1971), (Cartwright and Edden, 1973), (Tsukamoto, 1980a, 1980b), (Xi, 1985), (Büllesfeld, 1985) have developed the tide-generating potential till now for these purposes. The calculation of the theoretical tide directly from the positions of Moon and Sun requires less cost compared with the synthesis of harmonic constituents to obtain same accuracy (Tamura, 1982). But in tidal analysis, the determination of the amplitude factor and phase delay of each component is rather difficult if one uses the direct calculation method except response method.

The purpose of tidal analysis is to extract useful informations from observation data. If the theoretical tide computations in analysis have some errors, the output informations should be distorted. To avoid such situation, the theoretical values must keep much higher precision than that of recent earth tide observations.

The tidal constituents tables developed by Cartwright and Tayler (1971) and Cartwright and Edden (1973) are used as a standard now, but their developments are not so perfect and harmonic coefficients are given only five digits validity. More over, after their publication of tables, astronomical constants are revised. The author developed new harmonic tables of the tide-generating potential numerically using the MERIT (A programme of international collaboration to Monitor Earth

Rotation and Intercompare the Techniques of observation and analysis) standards (1983) and the JPL (Jet Propulsion Laboratory) ephemerides (Standish and Williams, 1981). These improved tables contain up to the fourth order potential which are derived from Moon, and also contain up to the third one from Sun. The amplitude coefficients in the tables are given in six figures under decimal point. In present development, all constituets, whose amplitudes are larger than 10×10^{-6} for the second order potential, 7×10^{-6} for the third one and 5×10^{-6} for the fourth one, are picked up. These amplitude thresholds are equivalent to 0.8n*Gal* for each order.

2. Arguments

Doodson and other authors who developed tidal potential used below six arguments to express phase and angular velocitiy for each constituent.

1 τ : time angle in lunar days

2 s : Moon's mean longitude

3 h : Sun's mean longitude

4 p : longitude of Moon's mean perigee

5 N' : negative longitude of Moon's mean node

6 p_1 : longitude of Sun's mean perigee

In above arguments, τ can be expressed with s and h ignoring the aberration and the difference between the dynamical time (TD) and the univarsal time (UT) as

$$\tau = 15^\circ\times t + h - s + \lambda \qquad (1)$$

where t is the univasal time in hour, and λ is the east longitude of a site. Those variables are related to the fundamental arguments of nutation series used in the MERIT standards by

$$\left.\begin{aligned} s &= F + \Omega, \\ h &= F + \Omega - D, \\ p &= F + \Omega - l, \\ N' &= -\Omega, \\ p_1 &= F + \Omega - D - l' \end{aligned}\right\} \quad (2)$$

where

F : Moon's mean elongation from node.

D : Moon's mean elongation from Sun.

Ω : longitude of Moon's perigee.

l : Moon's mean anomaly.

l' : Sun's mean anomaly.

In order to develope the tidal potential up to 10×10^{-6} amplitude constituents for the second order, following eight arguments are necessary. They are defined by the author as

$$\left.\begin{aligned} f_1 &= 15^\circ\times t + \alpha_m - s + \lambda, \\ f_2 &= s + \Delta s, \\ f_3 &= h + \Delta h, \\ f_4 &= p, \\ f_5 &= N', \\ f_6 &= p_1, \\ f_7 &: \text{ period of Jupiter's opposition.} \end{aligned}\right\} \quad (3)$$

f_8 : period of Venus's conjunction

where α_m is the right ascention of a *supposed* object to define the univasal time. Δs and Δh denote the long period perturbations in the longitude of Moon and Sun, respectively. These corrections of Δs and Δh are added to reduce the phase shift for the principal constituents such as O_1, K_1, M_2, S_2 and K_2. The existance of the arguments f_7 and f_8 does not mean the direct tidal effect by Jupiter and Venus, but the indirect effect of Sun generating potential by peturbing the earth's orbit.

Concerning the argument f_1, one should use α_m instead of h. There are differences between α_m and h in two points. For the first one, the time argument for α_m is UT, but h is TD. For the second one, there is a permanent difference of the aberration (about 20.″5) between their constant terms. If one uses h in place of α_m like Doodson's definition, tidal potential becomes to be calculated based on "apparent" places of Moon and Sun. On the other hand, if one uses α_m, tidal potential is calculated based on "true" places. In other words, when one compute the angle hour of an object whose right ascension is α, he calculates $h-\alpha$ in former case, and $\alpha_m-\alpha$ in later case. Though this difference between apparent and true places is only 20.″5, this gives systematic phase shift for all constituents. For example, all components of semidiurnal species are caused 0.°01 phase shift by this difference.

Since the gravitation operates as an "action at a distance"

(note gravity field is not energy propagation nor particle movement!), true place should be used in dynamics computations. (In addition, the aberration is a phenomenon propotinal to v/c, where v is the velocity of the earth's revolution, and c is the light velocity. Some forces propotinal to $(v/c)^2$ exist in theory of relativity.)

The eight arguments in equations (3) are concretely denoted as follows (Aoki *et al.*, 1982), (Kubo, 1980), (Bretagnon, 1982) (Chapront, 1982).

$$
\left.
\begin{aligned}
a_m &= 280.^\circ 4606184 + 36000.^\circ 7700536\,t_u + 0.^\circ 00038793\,t_u^2 \\
&\qquad - 0.^\circ 0000000258\,t_u^3, \\
s &= 218.^\circ 316656 + 481267.^\circ 881342\,t_d - 0.^\circ 001330\,t_d^2, \\
h &= 280.^\circ 466449 + 36000.^\circ 769822\,t_d + 0.^\circ 0003036\,t_d^2, \\
\Delta s &= 0.^\circ 0040 \cdot \cos(\ 29^\circ + 133^\circ t_d\ ), \\
\Delta h &= 0.^\circ 0018 \cdot \cos(\ 159^\circ + 19^\circ t_d\ ), \\
f_4 &= 83.^\circ 353243 + 4069.^\circ 013711\,t_d - 0.^\circ 010324\,t_d^2, \\
f_5 &= 234.^\circ 955444 + 1934.^\circ 136185\,t_d - 0.^\circ 002076\,t_d^2, \\
f_6 &= 282.^\circ 937348 + 1.^\circ 719533\,t_d + 0.^\circ 0004597\,t_d^2, \\
f_7 &= 248.^\circ 1 + 32964.^\circ 47\,t_d, \\
f_8 &= 81.^\circ 5 + 22518.^\circ 44\,t_d
\end{aligned}
\right\} \quad (4)
$$

where t_u is the universal time measured from 2000 Jan. 1 12^h UT1 (JD 2451545.0) in 36525 days unit, and t_d is the dynamical time measured from 2000 Jan. 1 12^h TD in 36525 days unit. The arguments s, h, p, N' and p_1 are slightly differ from the MERIT standards. But those differences are small enough to calculate the tidal potential.

3. Method of Development

Since the author developed the tide-generating potential numerically, his method is essentially the same as the way by Cartwright and Tayler (1971). The expansion process is simply explained as follows. At first, the tide-generating potential is calculated directly from the positions of Moon and Sun. Next, suitable sets of tidal constituents and their arguments are assumed. Lastly, the amplitude coefficients are determined by least square method, and the phases are checked whether the assumption of arguments is right or not.

In the development, there are some distinctive features compared with their expansion method. (1) Eight fundamental arguments are defined as mentioned in the previous section. (2) The filters, that Cartwright and Tayler designed to resolve the tidal constituents in the same species into subgroups defined by the argument f_2, are not used. Therefore, all amplitude coefficients of constituents in the same order and same species are determined in batch processing. The improvement of computer ability makes such a simple method possible. (3) Sampling

intervals for calculation of the tidal potential by direct method are 24, 6, 4, 3 and 2 hours for the long period, diurnal, semidiurnal, terdiurnal and 1/4 diurnal species, respectively. (4) In order to obtain the secular trends of the amplitudes of large constituents, four sets of coefficients are determined varying central epoch of 1960, 1980, 2000 and 2020 with 18.6 year data length. Using the preliminary determination of the secular trends of M_0S_0, K_1, O_1, M_2 and S_2, the variations of those principal terms are more precisely determined in the main computation. (5) Adopted ephemerides by JPL are given as numerical tables.

Figure 1 shows the flow of development process. The tables developed by Cartwright, Tayler and Edden are used as an initial set of the tidal constituents in this process.

As to paired constituents, whose frequencies differ only by $2f_6$, Xi's development is also initially used. For example, φ_1 constituent is formed with two terms of $f_1+f_2+2f_3-2f_6$ and $f_1+f_2+2f_3$. Numerical development can determine the amplitudes of such paired terms if the angular velocities are known, but it cannot determine what the coefficients of f_6 are. If the one of a pair's amplitude is smaller than 12×10^{-6}, those terms are represented by one term, whose angular velocity is the same as that of the bigger one, and whose amplitude is signified by "bigger one minus smaller one". This simplification is possible because the phase difference of $2f_6$ is $205^\circ \approx 180^\circ$ (see fig. 2).

The tidal potential P_{30} (third order long period tide) is

developed up to the 4×10^{-6} amplitude terms in present development. though the expansion threshold of the third order is adopted to 7×10^{-6}. Because Doodson mistaked its nomalization factor 2 for $2/\sqrt{5}$, that scale is also used in this time.

The constants used in present development are listed in table 1. The sine parallax of Moon is not included in the standards. but it is used conveniently. There is no trouble with the precision in the theoretical tide calclulations. if one uses the same value of Moon's sine parallax used in present development.

4. Results

The results of the harmonic development are shown in tables 2-20 to 2-44. The Moon origin constituents and Sun origin ones. which have the same frequencies. are combined in one term in the tables.

Noman but for Büllesfeld has developed the fourth order potential till now. because they are small and most cases negligible. But some constituents have the same frequencies of the second order terms. and have relative amplitudes of 10^{-3}. So the tidal factors of some second order potential may suffer modulation if one does not take the fourth order one into consideration in tidal analysis.

Several constituents are detected in present development. which are not listed in Xi's(1985) tables. though his threshold is 10×10^{-6} as same as mine. In opposition. several terms listed

in his tables have less than 5×10^{-6} amplitude or do not appear, and some small terms have opposite signs (table 3). This discrepancy may be caused by his treatment of five digits operations or the difference of nutation calculation.

The internal error of the amplitude coefficient, which is estimated from the deviation of amplitudes in four epochs, is $\pm1\times10^{-6}$ in present development. But some constituents (about 2% terms) have rather large deviations. Such large deviations may be caused by the small amplitude side bands.

In the second order potential, there are a few terms whose amplitudes are slightly larger than the threshold level of 10×10^{-6}, and whose frequencies and phases cannot be denoted by the combination of the eight arguments. They have angular velocities of about 0.4671 °/*h*, 12.8499 °/*h* and 13.3918 °/*h*, and have amplitudes of about 12×10^{-6}. This result shows that more precise harmonic development is difficult if one uses only traditional arguments which are defined by Doodson or the author.

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Table 1. Constants used in present development.

Geocentric Constant of Gravitation	$GE = 3.98600448\times10^{14}\mathrm{m^3s^{-2}}$
Heliocentric Constant of Gravitation	$GS = 1.3271244\times10^{20}\mathrm{m^3s^{-2}}$
Earth-Moon Mass Ratio	$\mu = 0.012300034$
Equatorial Radius of the Earth	$Re = 6378137\mathrm{m}$
Astronomical Unit	$au = 1.4959787066\times10^{11}\mathrm{m}$
Moon's Sine Parallax	$\sin \Pi = 3422.''448$

Table 2-20. Tidal harmonics derived from the potential P20. The amplitudes are normalized in Doodson's scale. The valiable T is the time measured from J2000.0 in 36525 days unit.

No.	Arguments Tau	S	H	P	N'	P	J	V	Angular V. deg./hour	Amplitude (-0.5 =< T =< 0.3) A	+ B * T
1	0	0	0	0	0	0			0.00000000	0.738300	0.000241
2	0	0	0	0	1	0			0.00220641	-0.065547	0.000027
3	0	0	0	0	2	0			0.00441281	0.000642	-0.000001
4	0	0	0	2	1	0			0.01149003	-0.000089	
5	0	0	0	2	2	0			0.01369644	-0.000034	
6	0	0	1	-1	0	0			0.03642683	-0.000020	
7	0	0	0	0	0	0	1	0	0.03760492	0.000011	
8	0	0	1	0	-1	-1			0.03886027	0.000098	
9	0	0	1	0	0	-1			0.04106668	0.011549	-0.000024
10	0	0	1	0	0	1			0.04107060	-0.000609	
11	0	0	1	0	1	-1			0.04327309	-0.000073	
12	0	0	1	0	1	1			0.04327701	0.000036	
13	0	0	0	0	0	0	0	2	0.05137677	-0.000011	
14	0	0	2	-2	-1	0			0.07064725	-0.000048	
15	0	0	2	-2	0	0			0.07285365	0.000732	0.000001
16	0	0	2	-2	1	0			0.07506006	-0.000073	
17	0	0	2	0	0	-2			0.08213336	0.000288	
18	0	0	2	0	0	0			0.08213728	0.072732	-0.000081
19	0	0	2	0	1	0			0.08434369	-0.001799	-0.000003
20	0	0	2	0	2	0			0.08655009	-0.000400	
21	0	0	2	0	3	0			0.08875650	0.000012	
22	0	0	3	-2	0	-1			0.11392033	0.000025	
23	0	0	3	0	0	-1			0.12320396	0.004246	-0.000014
24	0	0	3	0	1	-1			0.12541037	-0.000074	
25	0	0	3	0	2	-1			0.12761677	-0.000018	
26	0	0	4	0	0	-2			0.16427064	0.000173	
27	0	1	-4	1	-1	0			0.38717737	-0.000028	
28	0	1	-4	1	0	2			0.38938770	0.000021	
29	0	1	-4	3	0	0			0.39866740	0.000014	
30	0	1	-3	1	-1	1			0.42824797	-0.000051	
31	0	1	-3	1	0	1			0.43045438	0.000675	-0.000001
32	0	1	-3	1	1	1			0.43266078	-0.000042	
33	0	1	-2	-1	-2	0			0.45782461	-0.000056	
34	0	1	-2	-1	-1	0			0.46003102	-0.000153	
35	0	1	-2	1	-1	0			0.46931465	-0.001133	0.000001
36	0	1	-2	1	0	0			0.47152105	0.015791	0.000005
37	0	1	-2	1	1	0			0.47372746	-0.001025	0.000001
38	0	1	-2	1	2	0			0.47593387	0.000010	
39	0	1	-1	-1	-1	1			0.50110162	-0.000046	
40	0	1	-1	-1	0	1			0.50330803	0.000507	
41	0	1	-1	-1	1	1			0.50551443	-0.000027	
42	0	1	-1	0	-1	0			0.50574147	0.000033	
43	0	1	-1	0	0	0			0.50794788	-0.000458	-0.000001
44	0	1	-1	0	1	0			0.51015429	0.000032	
45	0	1	-1	1	0	-1			0.51258773	-0.000109	
46	0	1	0	-1	-2	0			0.53996189	0.000068	
47	0	1	0	-1	-1	0			0.54216830	-0.005419	0.000003
48	0	1	0	-1	0	0			0.54437471	0.082569	0.000027
49	0	1	0	-1	1	0			0.54658111	-0.005358	0.000007
50	0	1	0	-1	2	0			0.54878752	0.000052	

51	0 1 0 0 0-1	0.54901456	0.000068	
52	0 1 0 1 0 0	0.55365833	-0.004410	0.000004
53	0 1 0 1 1 0	0.55586474	-0.001798	0.000001
54	0 1 0 1 2 0	0.55807115	-0.000483	
55	0 1 0 1 3 0	0.56027755	0.000024	
56	0 1 1-1-1-1	0.58323498	0.000033	
57	0 1 1-1 0-1	0.58544138	-0.000426	
58	0 1 1-1 1-1	0.58764779	0.000017	
59	0 1 1 0 0 0	0.59008516	0.000027	
60	0 1 1 0 1 0	0.59229157	0.000011	
61	0 1 1 1 0-1	0.59472501	-0.000015	
62	0 1 1 1 1-1	0.59693142	-0.000009	
63	0 1 2-1 0 0	0.62651199	-0.001148	0.000001
64	0 1 2-1 1 0	0.62871839	-0.000574	
65	0 1 2-1 2 0	0.63092480	-0.000103	
66	0 1 3-1 0-1	0.66757866	-0.000055	
67	0 1 3-1 1-1	0.66978507	-0.000026	
68	0 2-5 2 0 1	0.90197543	0.000022	
69	0 2-4 0-1 0	0.93155207	-0.000025	
70	0 2-4 0 0 2	0.93376240	0.000041	
71	0 2-4 2-1 0	0.94083570	-0.000018	
72	0 2-4 2 0 0	0.94304211	0.000257	
73	0 2-4 2 1 0	0.94524851	-0.000017	
74	0 2-3 0-1 1	0.97262267	0.000023	
75	0 2-3 0 0 1	0.97482908	0.000902	-0.000001
76	0 2-3 0 1 1	0.97703549	-0.000057	
77	0 2-3 1 0 0	0.97946893	-0.000022	
78	0 2-2-2-1 0	1.00440573	-0.000013	
79	0 2-2 0-2 0	1.01148295	0.000029	
80	0 2-2 0-1 0	1.01368935	0.000977	
81	0 2-2 0 0 0	1.01589576	0.013695	0.000004
82	0 2-2 0 1 0	1.01810217	-0.000879	
83	0 2-2 0 2 0	1.02030857	0.000010	
84	0 2-2 2 0 0	1.02517939	-0.000089	
85	0 2-2 2 1 0	1.02738579	-0.000036	
86	0 2-2 2 2 0	1.02959220	-0.000013	
87	0 2-1-2 0 1	1.04768273	0.000083	
88	0 2-1-1 0 0	1.05232259	-0.000074	
89	0 2-1 0-1-1	1.05475603	-0.000029	
90	0 2-1 0 0-1	1.05696244	-0.000151	
91	0 2-1 0 0 1	1.05696636	0.000474	
92	0 2-1 0 1 1	1.05917277	0.000100	
93	0 2 0-2-1 0	1.08654301	-0.000360	
94	0 2 0-2 0 0	1.08874941	0.006767	0.000003
95	0 2 0-2 1 0	1.09095582	-0.000439	
96	0 2 0-1 0-1	1.09338926	0.000015	
97	0 2 0 0 0 0	1.09803304	0.156303	-0.000165
98	0 2 0 0 1 0	1.10023945	0.064805	-0.000035
99	0 2 0 0 2 0	1.10244585	0.006060	0.000001
100	0 2 0 0 3 0	1.10465226	-0.000130	
101	0 2 1-2 0-1	1.12981609	-0.000066	
102	0 2 1-1 0 0	1.13445987	0.000024	
103	0 2 1 0 0-1	1.13909972	-0.000537	
104	0 2 1 0 1-1	1.14130612	-0.000141	
105	0 2 2-2 0 0	1.17088669	-0.000469	
106	0 2 2-2 1 0	1.17309310	-0.000181	
107	0 2 2-2 2 0	1.17529951	-0.000022	
108	0 2 2 0 2 0	1.18458313	-0.000068	
109	0 2 2 0 3 0	1.18678954	-0.000025	

110	0 2 3-2 0-1	1.21195337	-0.000019	
111	0 3-5 1 0 1	1.44635013	0.000046	
112	0 3-4 1-1 0	1.48521041	0.000041	
113	0 3-4 1 0 0	1.48741681	0.000413	
114	0 3-4 1 1 0	1.48962322	-0.000030	
115	0 3-3-1 0 1	1.51920379	0.000158	
116	0 3-3-1 1 1	1.52141019	-0.000012	
117	0 3-3 1 0 1	1.52848741	0.000269	
118	0 3-3 1 1 1	1.53069382	0.000105	
119	0 3-2-1-1 0	1.55806406	0.000222	
120	0 3-2-1 0 0	1.56027047	0.002167	
121	0 3-2-1 1 0	1.56247687	-0.000140	
122	0 3-2 1 0 0	1.56955409	0.005684	-0.000006
123	0 3-2 1 1 0	1.57176050	0.002356	-0.000001
124	0 3-2 1 2 0	1.57396691	0.000213	
125	0 3-1-3 0 1	1.59205744	0.000010	
126	0 3-1-2 0 0	1.59669729	-0.000008	
127	0 3-1-1 0-1	1.60133714	-0.000035	
128	0 3-1-1 0 1	1.60134107	0.000279	
129	0 3-1-1 1 1	1.60354747	0.000097	
130	0 3-1 0 0 0	1.60598092	-0.000157	
131	0 3-1 0 1 0	1.60818733	-0.000066	
132	0 3-1 1 0-1	1.61062077	-0.000059	
133	0 3-1 1 1-1	1.61282718	-0.000020	
134	0 3 0-3-1 0	1.63091771	-0.000020	
135	0 3 0-3 0 0	1.63312412	0.000543	
136	0 3 0-3 1 0	1.63533053	-0.000035	
137	0 3 0-1 0 0	1.64240775	0.029926	-0.000033
138	0 3 0-1 1 0	1.64461415	0.012405	-0.000010
139	0 3 0-1 2 0	1.64682056	0.001161	-0.000001
140	0 3 0-1 3 0	1.64902697	-0.000019	
141	0 3 0 0 0-1	1.64704760	0.000026	
142	0 3 0 1 2 0	1.65610419	-0.000114	
143	0 3 0 1 3 0	1.65831059	-0.000047	
144	0 3 1-1 0-1	1.68347442	-0.000252	
145	0 3 1-1 1-1	1.68568083	-0.000088	
146	0 3 2-3 0 0	1.71526140	-0.000096	
147	0 3 2-3 1 0	1.71746781	-0.000037	
148	0 3 2-1 2 0	1.72895784	-0.000025	
149	0 3 2-1 3 0	1.73116425	-0.000010	
150	0 4-6 2 0 0	1.95893787	0.000009	
151	0 4-5 0 0 1	1.99072484	0.000027	
152	0 4-5 2 0 1	2.00000847	0.000013	
153	0 4-4 0-1 0	2.02958511	0.000044	
154	0 4-4 0 0 0	2.03179152	0.000211	
155	0 4-4 0 0 2	2.03179544	0.000016	
156	0 4-4 0 1 0	2.03399793	-0.000019	
157	0 4-4 2 0 0	2.04107515	0.000146	
158	0 4-4 2 1 0	2.04328155	0.000060	
159	0 4-3-2 0 1	2.06357849	0.000020	
160	0 4-3 0 0 1	2.07286212	0.000327	
161	0 4-3 0 1 1	2.07506853	0.000131	
162	0 4-2-2-1 0	2.10243877	0.000033	
163	0 4-2-2 0 0	2.10464517	0.000258	
164	0 4-2-2 1 0	2.10685158	-0.000017	
165	0 4-2 0 0 0	2.11392880	0.004779	-0.000005
166	0 4-2 0 1 0	2.11613521	0.001981	-0.000001
167	0 4-2 0 2 0	2.11834161	0.000185	

168	0 4-1-2 0 1	2.14571577	0.000066	
169	0 4-1-2 1 1	2.14792218	0.000023	
170	0 4-1-1 0 0	2.15035563	-0.000041	
171	0 4-1-1 1 0	2.15256203	-0.000018	
172	0 4-1 0 0-1	2.15499548	-0.000068	
173	0 4-1 0 1-1	2.15720188	-0.000025	
174	0 4 0-4 0 0	2.17749882	0.000043	
175	0 4 0-2 0 0	2.18678245	0.003960	-0.000005
176	0 4 0-2 1 0	2.18898886	0.001642	-0.000002
177	0 4 0-2 2 0	2.19119527	0.000158	
178	0 4 0 0 2 0	2.20047889	-0.000024	
179	0 4 0 0 3 0	2.20268530	-0.000010	
180	0 4 1-2 0-1	2.22784913	-0.000053	
181	0 4 1-2 1-1	2.23005554	-0.000020	
182	0 4 2-4 0 0	2.25963610	-0.000015	
183	0 5-5 1 0 1	2.54438317	0.000026	
184	0 5-5 1 1 1	2.54658958	0.000010	
185	0 5-4-1-1 0	2.57395982	0.000011	
186	0 5-4-1 0 0	2.57616623	0.000040	
187	0 5-4 1 0 0	2.58544985	0.000223	
188	0 5-4 1 1 0	2.58765626	0.000092	
189	0 5-3-1 0 1	2.61723683	0.000089	
190	0 5-3-1 1 1	2.61944323	0.000036	
191	0 5-2-3 0 0	2.64901988	0.000027	
192	0 5-2-1 0 0	2.65830351	0.001155	
193	0 5-2-1 1 0	2.66050991	0.000478	
194	0 5-2-1 2 0	2.66271632	0.000045	
195	0 5-1-3 0 1	2.69009048	0.000010	
196	0 5-1-1 0-1	2.69937018	-0.000022	
197	0 5 0-3 0 0	2.73115716	0.000446	
198	0 5 0-3 1 0	2.73336356	0.000185	
199	0 5 0-3 2 0	2.73556997	0.000018	
200	0 6-5 0 0 1	3.08875788	0.000016	
201	0 6-4 0 0 0	3.12982456	0.000119	
202	0 6-4 0 1 0	3.13203097	0.000049	
203	0 6-3-2 0 1	3.16161153	0.000016	
204	0 6-2-2 0 0	3.20267821	0.000191	
205	0 6-2-2 1 0	3.20488462	0.000079	
206	0 6 0-4 1 0	3.27773827	0.000019	
207	0 6 0-4 0 0	3.27553186	0.000046	
208	0 7-4-1 0 0	3.67419927	0.000032	
209	0 7-4-1 1 0	3.67640567	0.000013	
210	0 7-2-3 0 0	3.74705292	0.000026	
211	0 7-2-3 1 0	3.74925932	0.000011	

Table 2-21. Tidal harmonics derived from the potential P21.

No.	Arguments Tau S H P N'P J V	Angular V. deg./hour	Amplitude (-0.5 =< T =< 0.3) A	+ B * T
1	1-7 4 2 0 0	10.82249467	0.000015	
2	1-6 0 5 0 0	11.22116207	0.000011	
3	1-6 2 3-1 0	11.29180932	0.000012	
4	1-6 2 3 0 0	11.29401572	0.000063	
5	1-6 4 1-1 0	11.36466297	0.000014	
6	1-6 4 1 0 0	11.36686937	0.000076	
7	1-6 5 1 0-1	11.40793605	0.000011	
8	1-6 6-1 0 0	11.43972303	0.000015	
9	1-5 0 4-1 0	11.76333037	0.000021	
10	1-5 0 4 0 0	11.76553678	0.000110	
11	1-5 1 2 0 1	11.79732375	-0.000011	
12	1-5 2 2-1 0	11.83618402	0.000087	
13	1-5 2 2 0 0	11.83839043	0.000461	
14	1-5 3 2 0-1	11.87945711	0.000038	
15	1-5 4 0-1 0	11.90903767	0.000054	
16	1-5 4 0 0 0	11.91124408	0.000286	
17	1-5 5 0 0-1	11.95231076	0.000037	
18	1-5 6-2 0 0	11.98409773	0.000017	
19	1-4-1 3 0 1	12.26884480	-0.000020	
20	1-4 0 1-2 0	12.29621504	-0.000009	
21	1-4 0 3-1 0	12.30770508	0.000203	
22	1-4 0 3 0 0	12.30991148	0.001074	
23	1-4 1 1-1 1	12.33949205	-0.000009	
24	1-4 1 1 0 1	12.34169846	-0.000053	
25	1-4 1 2 0 0	12.34633831	-0.000017	
26	1-4 1 3 0-1	12.35097816	0.000023	
27	1-4 2-1-2 0	12.36906869	-0.000012	
28	1-4 2 1-2 0	12.37835232	-0.000014	
29	1-4 2 1-1 0	12.38055873	0.000525	
30	1-4 2 1 0 0	12.38276513	0.002783	-0.000002
31	1-4 2 3 0 0	12.39204876	-0.000010	
32	1-4 3-1 0 1	12.41455211	-0.000011	
33	1-4 3 0 0 0	12.41919196	-0.000014	
34	1-4 3 1-1-1	12.42162541	0.000039	
35	1-4 3 1 0-1	12.42383181	0.000210	
36	1-4 4-1-1 0	12.45341238	0.000101	
37	1-4 4-1 0 0	12.45561879	0.000538	
38	1-4 4 1 0 0	12.46490241	-0.000026	
39	1-4 4 1 1 0	12.46710882	0.000012	
40	1-4 5-1-1-1	12.49447906	0.000011	
41	1-4 5-1 0-1	12.49668547	0.000061	
42	1-3-2 4 0 0	12.78143254	-0.000036	
43	1-3-2 2-2 0	12.76773609	-0.000012	
44	1-3-1 2-1 1	12.81101310	-0.000022	
45	1-3-1 2 0 1	12.81321951	-0.000129	
46	1-3 0 0-3 0	12.83838334	-0.000011	
47	1-3 0 0-2 0	12.84058975	-0.000057	
48	1-3 0 2-2 0	12.84987337	-0.000045	
49	1-3 0 2-1 0	12.85207978	0.001801	-0.000005

50	1-3 0 2 0 0	12.85428619	0.009545	-0.000007
51	1-3 0 4 0 0	12.86356982	-0.000015	
52	1-3 1 0-1 1	12.88386676	-0.000028	
53	1-3 1 0 0 1	12.88607316	-0.000162	
54	1-3 1 1-1 0	12.88850661	-0.000019	
55	1-3 1 1 0 0	12.89071301	-0.000102	
56	1-3 1 2-1-1	12.89314646	0.000025	
57	1-3 1 2 0-1	12.89535287	0.000146	
58	1-3 2-2-2 0	12.91344340	-0.000013	
59	1-3 2 0-2 0	12.92272703	-0.000065	
60	1-3 2 0-1 0	12.92493343	0.002173	
61	1-3 2 0 0 0	12.92713984	0.011520	-0.000005
62	1-3 2 2 0 0	12.93642347	-0.000096	
63	1-3 2 2 1 0	12.93862987	0.000037	
64	1-3 3-1 0 0	12.96356667	-0.000029	
65	1-3 3 0-1-1	12.96600011	0.000144	
66	1-3 3 0 0-1	12.96820652	0.000776	-0.000001
67	1-3 4-2-1 0	12.99778709	0.000066	
68	1-3 4-2 0 0	12.99999349	0.000352	
69	1-3 4 0 0-2	13.00927320	0.000037	
70	1-3 4 0 0 0	13.00927712	-0.000075	
71	1-3 4 0 1 0	13.01148353	0.000049	
72	1-3 5-2 0-1	13.04106017	0.000032	
73	1-3 5 0 0-1	13.05034380	-0.000011	
74	1-2-2 1-3 0	13.30990439	-0.000011	
75	1-2-2 1-2 0	13.31211080	-0.000061	
76	1-2-2 3-1 0	13.32360083	-0.000040	
77	1-2-2 3 0 0	13.32580724	-0.000232	
78	1-2-1 1-1 1	13.35538781	-0.000097	
79	1-2-1 1 0 1	13.35759422	-0.000607	0.000001
80	1-2-1 2 0 0	13.36223407	0.000017	
81	1-2 0-1-3 0	13.38275805	-0.000052	
82	1-2 0-1-2 0	13.38496445	-0.000276	
83	1-2 0 0 0 1	13.39402104	0.000052	
84	1-2 0 1-2 0	13.39424808	-0.000411	-0.000003
85	1-2 0 1-1 0	13.39645449	0.013607	-0.000003
86	1-2 0 1 0 0	13.39866089	0.072136	-0.000035
87	1-2 0 3 0 0	13.40794452	-0.000195	
88	1-2 0 3 1 0	13.41015093	-0.000022	
89	1-2 1-1-1 1	13.42824146	-0.000022	
90	1-2 1-1 0 1	13.43044787	-0.000133	
91	1-2 1 0-1 0	13.43288131	-0.000072	
92	1-2 1 0 0 0	13.43508772	-0.000390	0.000001
93	1-2 1 1-1-1	13.43752117	0.000109	
94	1-2 1 1 0-1	13.43972757	0.000673	-0.000001
95	1-2 1 1 0 1	13.43973150	0.000013	
96	1-2 1 1 1 1	13.44193790	-0.000009	
97	1-2 2-1-2 0	13.46710173	-0.000077	
98	1-2 2-1-1 0	13.46930814	0.002584	
99	1-2 2-1 0 0	13.47151455	0.013702	-0.000006
100	1-2 2 1-1 0	13.47859177	0.000021	
101	1-2 2 1 0 0	13.48079817	-0.000789	
102	1-2 2 1 1 0	13.48300458	0.000244	
103	1-2 3-1-1-1	13.51037482	0.000116	
104	1-2 3-1 0-1	13.51258123	0.000630	
105	1-2 3 1 0-1	13.52186485	-0.000057	
106	1-2 3 1 1-1	13.52407126	0.000009	
107	1-2 4-1 0-2	13.55364790	0.000023	
108	1-2 4-1 0 0	13.55365183	-0.000151	

109	1-2 4-1 1 0	13.55585823	0.000045	
110	1-2 5-1 0-1	13.59471851	-0.000017	
111	1-1-3 2 0 1	13.82911527	-0.000046	
112	1-1-2 0-3 0	13.85427910	-0.000028	
113	1-1-2 0-2 0	13.85648551	-0.000163	
114	1-1-2 0 0 2	13.86090224	-0.000013	
115	1-1-2 2-1 0	13.86797554	-0.000198	
116	1-1-2 2 0 0	13.87018195	-0.001132	
117	1-1-1 0-1 1	13.89976251	-0.000154	
118	1-1-1 0 0 1	13.90196892	-0.001296	0.000002
119	1-1-1 1 0 0	13.90660877	0.000057	
120	1-1-1 2 0 1	13.91125255	0.000033	
121	1-1 0-2-2 0	13.92933916	0.000014	
122	1-1 0 0-3 0	13.93641638	0.000021	
123	1-1 0 0-2 0	13.93862279	-0.002178	0.000003
124	1-1 0 0-1 0	13.94082919	0.071081	0.000020
125	1-1 0 0 0 0	13.94303560	0.376763	-0.000178
126	1-1 0 0 1 0	13.94524201	0.000015	
127	1-1 0 2-1 0	13.95011282	0.000070	
128	1-1 0 2 0 0	13.95231923	-0.002429	0.000002
129	1-1 0 2 1 0	13.95452563	-0.000396	
130	1-1 0 2 2 0	13.95673204	0.000015	
131	1-1 1-1 0 0	13.97946243	-0.000014	
132	1-1 1 0-1-1	13.98189587	0.000119	
133	1-1 1 0 0-1	13.98410228	0.001141	-0.000002
134	1-1 1 0 0 1	13.98410620	0.000055	
135	1-1 1 0 1 1	13.98631261	-0.000035	
136	1-1 1 1 0 0	13.98874605	0.000025	
137	1-1 1 2 0-1	13.99338591	-0.000030	
138	1-1 2-2-1 0	14.01368285	-0.000040	
139	1-1 2-2 0 0	14.01588925	-0.000215	
140	1-1 2 0-1 0	14.02296647	0.000140	
141	1-1 2 0 0-2	14.02516896	0.000014	
142	1-1 2 0 0 0	14.02517288	-0.004914	0.000002
143	1-1 2 0 1 0	14.02737929	0.001071	
144	1-1 2 0 2 0	14.02958569	0.000072	
145	1-1 3-2 0-1	14.05695593	-0.000010	
146	1-1 3 0-1-1	14.06403315	0.000010	
147	1-1 3 0 0-1	14.06623956	-0.000324	
148	1-1 3 0 1-1	14.06844597	0.000025	
149	1-1 4-2 0 0	14.09802653	-0.000092	
150	1-1 4-2 1 0	14.10023294	-0.000019	
151	1-1 4 0 0-2	14.10730624	-0.000015	
152	1 0-3 1-1 1	14.37128357	-0.000028	
153	1 0-3 1 0 1	14.37348998	-0.000133	
154	1 0-2-1-2 0	14.40086021	0.000009	
155	1 0-2 1-2 0	14.41014384	0.000037	
156	1 0-2 1-1 0	14.41235025	-0.000629	
157	1 0-2 1 0 0	14.41455665	-0.002780	
158	1 0-1-1-1 1	14.44413722	-0.000010	
159	1 0-1-1 0 1	14.44634363	-0.000044	
160	1 0-1 0-1 0	14.44877707	0.000012	
161	1 0-1 0 0 0	14.45098348	0.000064	
162	1 0-1 1 0 1	14.45562726	0.000146	
163	1 0-1 1 1 1	14.45783366	0.000036	
164	1 0 0-1-2 0	14.48299749	0.000173	
165	1 0 0-1-1 0	14.48520390	-0.001972	-0.000001
166	1 0 0-1 0 0	14.48741031	-0.010653	0.000005

167	1 0 0 0 0-1	14.49205016	-0.000014	
168	1 0 0 0 0 1	14.49205408	-0.000037	
169	1 0 0 1-1 0	14.49448753	0.000856	0.000002
170	1 0 0 1 0 0	14.49669393	-0.029631	0.000013
171	1 0 0 1 1 0	14.49890034	-0.005946	-0.000001
172	1 0 0 1 2 0	14.50110675	0.000167	
173	1 0 1-1 0-1	14.52847698	0.000012	
174	1 0 1-1 0 1	14.52848091	0.000037	
175	1 0 1 0 0 0	14.53312076	0.000164	
176	1 0 1 0 1 0	14.53532717	0.000036	
177	1 0 1 1 0-1	14.53776061	-0.000183	
178	1 0 1 1 1-1	14.53996702	-0.000046	
179	1 0 2-1-1 0	14.56734118	0.000164	
180	1 0 2-1 0 0	14.56954759	-0.005667	0.000003
181	1 0 2-1 1 0	14.57175399	-0.001244	
182	1 0 2-1 2 0	14.57396040	0.000029	
183	1 0 2 1 1 0	14.58103762	0.000025	
184	1 0 2 1 2 0	14.58324403	0.000020	
185	1 0 3-1 0-1	14.61061426	-0.000242	
186	1 0 3-1 1-1	14.61282067	-0.000056	
187	1 1-5 0 0 3	14.83573132	0.000014	
188	1 1-4 0 0 2	14.87679800	0.000416	
189	1 1-2 0 0 0 0-2	14.90755459	-0.000008	
190	1 1-3 0-1 1	14.91565827	-0.000081	
191	1 1-3 0 0 1	14.91786468	0.010251	-0.000030
192	1 1-2 0 0 0-1 0	14.92132644	0.000011	
193	1 1-3 2 0 1	14.92714831	-0.000009	
194	1 1-2 0-2 0	14.95451855	0.000143	
195	1 1-2 0-1 0	14.95672495	-0.001973	-0.000006
196	1 1-2 0 0 0	14.95893136	0.175307	-0.000083
197	1 1-2 0 0 2	14.95893528	-0.000112	
198	1 1-2 2-1 0	14.96600858	0.000013	
199	1 1-2 2 0 0	14.96821499	-0.000263	
200	1 1-2 2 1 0	14.97042139	-0.000053	
201	1 1-1 0-1-1	14.99779163	0.000029	
202	1 1-1 0 0-1	14.99999804	-0.001467	0.000005
203	1 1-1 0 0 1	15.00000196	-0.004145	0.000015
204	1 1-1 0 1 1	15.00220837	0.000108	
205	1 1 0-2-2 0	15.02737220	0.000012	
206	1 1 0-2-1 0	15.02957861	-0.000097	
207	1 1 0 0-2 0	15.03665583	-0.000067	
208	1 1 0 0-1 0	15.03886223	0.010492	-0.000008
209	1 1 0 0 0 0	15.04106864	-0.529876	0.000224
210	1 1 0 0 0 2	15.04107256	0.000019	
211	1 1 0 0 1 0	15.04327505	-0.071886	-0.000019
212	1 1 0 0 2 0	15.04548145	0.001543	
213	1 1 0 2 1 0	15.05255867	0.000014	
214	1 1 0 2 2 0	15.05476508	0.000012	
215	1 1 1 0-1-1	15.07992891	-0.000013	
216	1 1 1 0 0-1	15.08213532	-0.004145	0.000013
217	1 1 1 0 0 1	15.08213924	0.000063	
218	1 1 1 0 1-1	15.08434173	-0.000075	
219	1 1 2-2 0 0	15.11392229	-0.000263	
220	1 1 2-2 1 0	15.11612870	-0.000073	
221	1 1 2 0 0-2	15.12320200	-0.000104	
222	1 1 2 0 0 0	15.12320592	-0.007545	0.000011
223	1 1 2 0 1 0	15.12541233	0.000289	
224	1 1 2 0 2 0	15.12761873	0.000143	
225	1 1 2 0 3 0	15.12982514	0.000013	

226	1 1 3-2 0-1	15.15498897	-0.000009	
227	1 1 3 0 0-1	15.16427260	-0.000439	
228	1 1 3 0 1-1	15.16647901	0.000012	
229	1 1 4 0 0-2	15.20533928	-0.000018	
230	1 2-4 1-1 0	15.42824601	-0.000032	
231	1 2-4 1 0 2	15.43045634	-0.000012	
232	1 2-3 0 0 0	15.46687924	-0.000013	
233	1 2-3 1 0 1	15.47152302	-0.000242	
234	1 2-3 1 1 1	15.47372942	-0.000047	
235	1 2-2-1-2 0	15.49889325	0.000020	
236	1 2-2-1-1 0	15.50109966	-0.000168	
237	1 2-2-1 0 0	15.50330607	0.000029	
238	1 2-2 1-1 0	15.51038329	0.000181	
239	1 2-2 1 0 0	15.51258969	-0.005666	0.000002
240	1 2-2 1 1 0	15.51479610	-0.001124	
241	1 2-2 1 2 0	15.51700251	0.000024	
242	1 2-1-1 0 1	15.54437667	-0.000182	
243	1 2-1-1 1 1	15.54658307	-0.000031	
244	1 2-1 0 0 0	15.54901652	0.000164	
245	1 2-1 0 1 0	15.55122293	0.000028	
246	1 2-1 1 0-1	15.55365637	0.000038	
247	1 2 0-1-1 0	15.58323694	0.000868	
248	1 2 0-1 0 0	15.58544335	-0.029630	0.000012
249	1 2 0-1 1 0	15.58764975	-0.005875	
250	1 2 0-1 2 0	15.58985616	0.000124	
251	1 2 0 0 0-1	15.59008320	-0.000022	
252	1 2 0 1 0 0	15.59472697	0.000455	
253	1 2 0 1 1 0	15.59693338	0.000287	
254	1 2 0 1 2 0	15.59913979	0.000173	
255	1 2 0 1 3 0	15.60134619	0.000026	
256	1 2 1-1 0-1	15.62651002	0.000152	
257	1 2 1-1 1-1	15.62871643	0.000023	
258	1 2 2-1 0 0	15.66758063	0.000118	
259	1 2 2-1 1 0	15.66978703	0.000092	
260	1 2 2-1 2 0	15.67199344	0.000037	
261	1 3-4 0-1 0	15.97262071	-0.000027	
262	1 3-4 0 0 2	15.97483104	-0.000019	
263	1 3-4 2 0 0	15.98411075	-0.000092	
264	1 3-4 2 1 0	15.98631715	-0.000018	
265	1 3-3 0 0 1	16.01589772	-0.000324	
266	1 3-3 0 1 1	16.01810413	-0.000062	
267	1 3-2-2-1 0	16.04547437	-0.000015	
268	1 3-2 0-1 0	16.05475799	-0.000157	
269	1 3-2 0 0 0	16.05696440	-0.004915	0.000003
270	1 3-2 0 1 0	16.05917081	-0.000962	
271	1 3-2 0 2 0	16.06137721	0.000020	
272	1 3-2 2 0 0	16.06624803	0.000009	
273	1 3-1-2 0 1	16.08875137	-0.000030	
274	1 3-1-1 0 0	16.09339123	0.000026	
275	1 3-1 0 0-1	16.09803108	0.000053	
276	1 3-1 0 0 1	16.09803500	-0.000049	
277	1 3-1 0 1 1	16.10024141	-0.000026	
278	1 3 0-2-1 0	16.12761165	0.000058	
279	1 3 0-2 0 0	16.12981805	-0.002428	0.000002
280	1 3 0-2 1 0	16.13202446	-0.000481	
281	1 3 0 0 0 0	16.13910168	-0.016212	0.000026
282	1 3 0 0 1 0	16.14130809	-0.010385	0.000012
283	1 3 0 0 2 0	16.14351449	-0.002175	0.000001

284	1 3 0 0 3 0	16.14572090	-0.000142	
285	1 3 1-2 0-1	16.17088473	0.000024	
286	1 3 1 0 0-1	16.18016836	0.000056	
287	1 3 1 0 1-1	16.18237476	0.000023	
288	1 3 2-2 0 0	16.21195533	0.000048	
289	1 3 2-2 1 0	16.21416174	0.000029	
290	1 4-5 1 0 1	16.48741877	-0.000017	
291	1 4-4 1 0 0	16.52848545	-0.000150	
292	1 4-4 1 1 0	16.53069186	-0.000029	
293	1 4-3-1 0 1	16.56027243	-0.000057	
294	1 4-3-1 1 1	16.56247883	-0.000011	
295	1 4-3 1 0 1	16.56955605	-0.000030	
296	1 4-3 1 1 1	16.57176246	-0.000017	
297	1 4-2-1-1 0	16.59913270	-0.000036	
298	1 4-2-1 0 0	16.60133911	-0.000779	
299	1 4-2-1 1 0	16.60354551	-0.000152	
300	1 4-2 1 0 0	16.61062273	-0.000590	
301	1 4-2 1 1 0	16.61282914	-0.000377	
302	1 4-2 1 2 0	16.61503555	-0.000076	
303	1 4-1-1 0-1	16.64240578	0.000012	
304	1 4-1-1 0 1	16.64240971	-0.000029	
305	1 4-1-1 1 1	16.64461611	-0.000018	
306	1 4-1 0 0 0	16.64704956	0.000015	
307	1 4-1 0 1 0	16.64925597	0.000010	
308	1 4 0-3 0 0	16.67419276	-0.000195	
309	1 4 0-3 1 0	16.67639917	-0.000039	
310	1 4 0-1 0 0	16.68347639	-0.003104	0.000005
311	1 4 0-1 1 0	16.68568279	-0.001988	0.000002
312	1 4 0-1 2 0	16.68788920	-0.000419	0.000001
313	1 4 0-1 3 0	16.69009561	-0.000028	
314	1 4 0 1 2 0	16.69717283	0.000012	
315	1 4 1-1 0-1	16.72454306	0.000026	
316	1 4 1-1 1-1	16.72674947	0.000014	
317	1 4 2-3 0 0	16.75633004	0.000010	
318	1 5-5 0 0 1	17.03179348	-0.000010	
319	1 5-4 0 0 0	17.07286016	-0.000074	
320	1 5-4 0 1 0	17.07506657	-0.000014	
321	1 5-4 2 0 0	17.08214379	-0.000015	
322	1 5-3 0 0 1	17.11393076	-0.000035	
323	1 5-3 0 1 1	17.11613717	-0.000021	
324	1 5-2-2 0 0	17.14571381	-0.000093	
325	1 5-2-2 1 0	17.14792022	-0.000018	
326	1 5-2 0 0 0	17.15499744	-0.000496	
327	1 5-2 0 1 0	17.15720385	-0.000317	
328	1 5-2 0 2 0	17.15941025	-0.000066	
329	1 5 0-4 0 0	17.21856746	-0.000016	
330	1 5 0-2 0 0	17.22785109	-0.000411	
331	1 5 0-2 1 0	17.23005750	-0.000263	
332	1 5 0-2 2 0	17.23226391	-0.000056	
333	1 6-4-1 0 0	17.61723487	-0.000015	
334	1 6-4 1 0 0	17.62651849	-0.000023	
335	1 6-4 1 1 0	17.62872490	-0.000015	
336	1 6-3-1 0 1	17.65830547	-0.000009	
337	1 6-2-3 0 0	17.69008852	-0.000010	
338	1 6-2-1 0 0	17.69937215	-0.000120	
339	1 6-2-1 1 0	17.70157855	-0.000077	
340	1 6-2-1 2 0	17.70378496	-0.000016	

341	1 6 0-3 0 0	17.77222580	-0.000046
342	1 6 0-3 1 0	17.77443220	-0.000030
343	1 7-4 0 0 0	18.17089320	-0.000012
344	1 7-2-2 0 0	18.24374685	-0.000020
345	1 7-2-2 1 0	18.24595326	-0.000013

Table 2-22. Tidal harmonics derived from the potential P22.

No.	Arguments Tau S H P N'P J V	Angular V. deg./hour	Amplitude (-0.5 =< T =< 0.3) A	+ B * T
1	2-6 2 4 0 0	25.79070966	0.000018	
2	2-6 4 2 0 0	25.86356331	0.000035	
3	2-6 6 0 0 0	25.93641696	0.000016	
4	2-5 0 5 0 0	26.26223071	0.000026	
5	2-5 2 3 0 0	26.33508436	0.000151	
6	2-5 3 3 0-1	26.37615104	0.000014	
7	2-5 4 1 0 0	26.40793801	0.000183	
8	2-5 5 1 0-1	26.44900469	0.000026	
9	2-5 6-1 0 0	26.48079167	0.000036	
10	2-4 0 4-1 0	26.80439901	-0.000010	
11	2-4 0 4 0 0	26.80660542	0.000265	
12	2-4 1 2 0 1	26.83839239	-0.000027	
13	2-4 2 2-1 0	26.87725266	-0.000042	
14	2-4 2 2 0 0	26.87945907	0.001111	
15	2-4 3 0 0 1	26.91124604	-0.000017	
16	2-4 3 1 0 0	26.91588589	-0.000009	
17	2-4 3 2 0-1	26.92052575	0.000092	
18	2-4 4 0-1 0	26.95010631	-0.000026	
19	2-4 4 0 0 0	26.95231272	0.000689	
20	2-4 5 0 0-1	26.99337940	0.000090	
21	2-4 6-2 0 0	27.02516637	0.000042	
22	2-3-2 5 0 0	27.27812647	-0.000011	
23	2-3-1 3 0 1	27.30991344	-0.000049	
24	2-3 0 1-2 0	27.33728368	-0.000022	
25	2-3 0 3-1 0	27.34877372	-0.000097	
26	2-3 0 3 0 0	27.35098012	0.002589	
27	2-3 1 1 0 1	27.38276710	-0.000128	
28	2-3 1 2 0 0	27.38740695	-0.000041	
29	2-3 1 3 0-1	27.39204680	0.000055	
30	2-3 2-1-2 0	27.41013733	-0.000028	
31	2-3 2 1-1 0	27.42162737	-0.000250	
32	2-3 2 1 0 0	27.42383377	0.006709	
33	2-3 3-1 0 1	27.45562075	-0.000026	
34	2-3 3 0 0 0	27.46026060	-0.000032	
35	2-3 3 1-1-1	27.46269405	-0.000019	
36	2-3 3 1 0-1	27.46490045	0.000508	
37	2-3 4-1-1 0	27.49448102	-0.000048	
38	2-3 4-1 0 0	27.49668743	0.001296	
39	2-3 4 1 0-2	27.50596713	0.000023	
40	2-3 5-1 0-1	27.53775411	0.000147	
41	2-3 6-3 0 0	27.56954108	0.000019	
42	2-2-2 2-2 0	27.80880473	-0.000029	
43	2-2-2 4 0 0	27.82250118	-0.000086	
44	2-2-1 2-1 1	27.85208174	0.000010	
45	2-2-1 2 0 1	27.85428815	-0.000311	
46	2-2 0 0-2 0	27.88165839	-0.000138	
47	2-2 0 1 0 1	27.89071498	0.000046	
48	2-2 0 2-1 0	27.89314842	-0.000859	
49	2-2 0 2 0 0	27.89535483	0.023009	0.000003
50	2-2 1 0-1 1	27.92493540	0.000013	

51	2-2 1 0 0 1	27.92714180	-0.000392	
52	2-2 1 1 0 0	27.93178165	-0.000246	
53	2-2 1 2-1-1	27.93421510	-0.000012	
54	2-2 1 2 0-1	27.93642151	0.000356	
55	2-2 2-2-2 0	27.95451204	-0.000033	
56	2-2 2 0-2 0	27.96379567	0.000019	
57	2-2 2 0-1 0	27.96600207	-0.001037	-0.000001
58	2-2 2 0 0 0	27.96820848	0.027768	0.000002
59	2-2 2 2 0 0	27.97749211	0.000013	
60	2-2 2 2 1 0	27.97969851	-0.000017	
61	2-2 3-2 0 1	27.99999545	-0.000013	
62	2-2 3-1 0 0	28.00463531	-0.000064	
63	2-2 3 0-1-1	28.00706875	-0.000069	
64	2-2 3 0 0-1	28.00927516	0.001874	-0.000003
65	2-2 4-2-1 0	28.03885573	-0.000031	
66	2-2 4-2 0 0	28.04106213	0.000848	
67	2-2 4 0 0-2	28.05034184	0.000090	
68	2-2 4 0 0 0	28.05034576	0.000016	
69	2-2 4 0 1 0	28.05255217	-0.000023	
70	2-2 5-2 0-1	28.08212881	0.000076	
71	2-1-3 3 0 1	28.32580920	-0.000019	
72	2-1-2 1-2 0	28.35317944	-0.000147	
73	2-1-2 1 0 2	28.35759618	-0.000012	
74	2-1-2 3-1 0	28.36466947	0.000019	
75	2-1-2 3 0 0	28.36687588	-0.000560	
76	2-1-1 1-1 1	28.39645645	0.000047	
77	2-1-1 1 0 1	28.39866286	-0.001463	0.000003
78	2-1-1 2 0 0	28.40330271	0.000040	
79	2-1 0-1-3 0	28.42382669	0.000025	
80	2-1 0-1-2 0	28.42603309	-0.000666	
81	2-1 0-1 0 2	28.43044983	-0.000020	
82	2-1 0 0 0 1	28.43508968	0.000140	
83	2-1 0 1-2 0	28.43531672	0.000092	
84	2-1 0 1-1 0	28.43752313	-0.006484	-0.000002
85	2-1 0 1 0 0	28.43972953	0.173881	0.000015
86	2-1 0 3 0 0	28.44901316	0.000042	
87	2-1 0 3 1 0	28.45121957	0.000011	
88	2-1 1-1-1 1	28.46931010	0.000011	
89	2-1 1-1 0 1	28.47151651	-0.000323	
90	2-1 1 0-1 0	28.47394995	0.000034	
91	2-1 1 0 0 0	28.47615636	-0.000937	
92	2-1 1 1-1-1	28.47858981	-0.000052	
93	2-1 1 1 0-1	28.48079621	0.001625	-0.000002
94	2-1 2-1-2 0	28.50817037	0.000016	
95	2-1 2-1-1 0	28.51037678	-0.001232	0.000001
96	2-1 2-1 0 0	28.51258319	0.033027	0.000002
97	2-1 2 1 0-2	28.52186289	0.000028	
98	2-1 2 1 0 0	28.52186681	0.000169	
99	2-1 2 1 1 0	28.52407322	-0.000116	
100	2-1 2 1 2 0	28.52627963	-0.000013	
101	2-1 3-2 0 0	28.54901001	-0.000009	
102	2-1 3-1-1-1	28.55144346	-0.000056	
103	2-1 3-1 0-1	28.55364987	0.001525	-0.000002
104	2-1 3 1 0-1	28.56293349	0.000011	
105	2-1 4-1 0-2	28.59471654	0.000055	
106	2-1 4-1 0 0	28.59472047	0.000033	
107	2-1 4-1 1 0	28.59692687	-0.000021	
108	2 0-3 0-2 1	28.85648747	-0.000016	

109	2 0-3 2 0 1	28.87018391	-0.000110	
110	2 0-2 0-3 0	28.89534774	0.000013	
111	2 0-2 0-2 0	28.89755415	-0.000394	
112	2 0-2 0 0 2	28.90197088	-0.000030	
113	2 0-2 2-1 0	28.90904418	0.000095	
114	2 0-2 2 0 0	28.91125059	-0.002728	-0.000001
115	2 0-1 0-1 1	28.94083115	0.000074	
116	2 0-1 0 0 1	28.94303756	-0.003123	0.000008
117	2 0-1 1 0 0	28.94767741	0.000137	
118	2 0-1 2 0-1	28.95231727	-0.000016	
119	2 0 0-2-2 0	28.97040780	0.000032	
120	2 0 0 0-2 0	28.97969143	0.000472	
121	2 0 0 0-1 0	28.98189783	-0.033885	0.000020
122	2 0 0 0 0 0	28.98410424	0.908184	0.000086
123	2 0 0 0 1 0	28.98631065	0.000019	
124	2 0 0 1 0-1	28.98874409	-0.000010	
125	2 0 0 2-1 0	28.99118146	-0.000010	
126	2 0 0 2 0 0	28.99338787	0.000525	-0.000001
127	2 0 0 2 1 0	28.99559427	0.000189	
128	2 0 0 2 2 0	28.99780068	0.000036	
129	2 0 1-2 0 1	29.01589121	0.000011	
130	2 0 1-1 0 0	29.02053107	-0.000032	
131	2 0 1 0-1-1	29.02296451	-0.000057	
132	2 0 1 0 0-1	29.02517092	0.002749	-0.000007
133	2 0 1 0 0 1	29.02517484	-0.000012	
134	2 0 1 0 1 1	29.02738125	0.000017	
135	2 0 1 1 0 0	29.02981469	-0.000009	
136	2 0 2-2-1 0	29.05475149	0.000019	
137	2 0 2-2 0 0	29.05695789	-0.000518	
138	2 0 2 0-1 0	29.06403511	-0.000019	
139	2 0 2 0 0-2	29.06623760	0.000033	
140	2 0 2 0 0 0	29.06624152	0.001066	
141	2 0 2 0 1 0	29.06844793	-0.000510	
142	2 0 2 0 2 0	29.07065433	0.000173	
143	2 0 3-2 0-1	29.09802457	-0.000023	
144	2 0 3 0 0-1	29.10730820	0.000070	
145	2 0 3 0 1-1	29.10951461	-0.000012	
146	2 0 4-2 0 0	29.13909517	0.000021	
147	2 0 4-2 1 0	29.14130158	0.000009	
148	2 1-4 1 0 2	29.37349194	-0.000013	
149	2 1-3 1-1 1	29.41235221	0.000013	
150	2 1-3 1 0 1	29.41455862	-0.000321	
151	2 1-2-1-2 0	29.44192885	0.000022	
152	2 1-2 1-1 0	29.45341889	0.000300	
153	2 1-2 1 0 0	29.45562529	-0.006697	
154	2 1-1-1 0 1	29.48741227	-0.000103	
155	2 1-1 0 0 0	29.49205212	0.000156	
156	2 1-1 1 0-1	29.49669197	0.000016	
157	2 1-1 1 0 1	29.49669590	-0.000033	
158	2 1-1 1 1 1	29.49890230	-0.000017	
159	2 1 0-1-2 0	29.52406613	-0.000038	
160	2 1 0-1-1 0	29.52627254	0.000939	-0.000001
161	2 1 0-1 0 0	29.52847895	-0.025670	-0.000002
162	2 1 0 0 0-1	29.53311880	-0.000024	
163	2 1 0 1-1 0	29.53555617	-0.000119	
164	2 1 0 1 0 0	29.53776257	0.006420	-0.000008
165	2 1 0 1 1 0	29.53996898	0.002832	-0.000002
166	2 1 0 1 2 0	29.54217539	0.000400	
167	2 1 1-1 0-1	29.56954562	0.000038	

168	2 1 1 0 0 0	29.57418940	-0.000036	
169	2 1 1 0 1 0	29.57639581	-0.000016	
170	2 1 1 1 0-1	29.57882925	0.000038	
171	2 1 1 1 1-1	29.58103566	0.000022	
172	2 1 2-1-1 0	29.60840982	-0.000023	
173	2 1 2-1 0 0	29.61061623	0.001228	-0.000001
174	2 1 2-1 1 0	29.61282263	0.000592	
175	2 1 2-1 2 0	29.61502904	0.000069	
176	2 1 3-1 0-1	29.65168290	0.000052	
177	2 1 3-1 1-1	29.65388931	0.000026	
178	2 2-5 0 0 3	29.87679996	0.000035	
179	2 2-4 0 0 2	29.91786664	0.001002	-0.000002
180	2 2-2 0 0 0-2 0	29.92479017	0.000011	
181	2 2-2 0 0 0 0-2	29.94862323	-0.000021	
182	2 2-3 0-1 1	29.95672691	0.000038	
183	2 2-3 0 0 1	29.95893332	0.024701	-0.000059
184	2 2-2 0 0 0-1 0	29.96239508	0.000025	
185	2 2-2 0 0 0 0-1	29.97431161	0.000013	
186	2 2-2 0-2 0	29.99558719	-0.000030	
187	2 2-2 0-1 0	29.99779359	0.000946	-0.000004
188	2 2-2 0 0 0	30.00000000	0.422535	0.000040
189	2 2-2 2 0 0	30.00928363	0.000057	
190	2 2-2 2 1 0	30.01149003	0.000025	
191	2 2-1 0-1-1	30.03886027	-0.000017	
192	2 2-1 0 0-1	30.04106668	-0.003536	0.000010
193	2 2-1 0 0 1	30.04107060	0.000899	
194	2 2-1 0 1 1	30.04327701	-0.000052	
195	2 2-1 0 2 1	30.04548342	-0.000012	
196	2 2 0-2-1 0	30.07064725	0.000046	
197	2 2 0-2 0 0	30.07285365	0.000011	
198	2 2 0 0-1 0	30.07993087	-0.001472	-0.000002
199	2 2 0 0 0 0	30.08213728	0.114860	-0.000121
200	2 2 0 0 1 0	30.08434369	0.034240	-0.000021
201	2 2 0 0 2 0	30.08655009	0.003718	-0.000002
202	2 2 1 0 0-1	30.12320396	0.000904	-0.000001
203	2 2 1 0 1-1	30.12541037	0.000038	
204	2 2 1 0 2-1	30.12761677	0.000008	
205	2 2 2-2 0 0	30.15499093	0.000057	
206	2 2 2-2 1 0	30.15719734	0.000035	
207	2 2 2 0 0-2	30.16427064	0.000022	
208	2 2 2 0 0 0	30.16427456	0.000782	
209	2 2 2 0 1 0	30.16648097	-0.000041	
210	2 2 2 0 2 0	30.16868737	-0.000031	
211	2 2 3 0 0-1	30.20534124	0.000045	
212	2 3-4 1-1 0	30.46931465	0.000015	
213	2 3-4 1 0 0	30.47152105	0.000009	
214	2 3-3 0 0 0	30.50794788	-0.000032	
215	2 3-3 1 0 1	30.51259166	0.000053	
216	2 3-3 1 1 1	30.51479806	0.000022	
217	2 3-2-1-1 0	30.54216830	0.000080	
218	2 3-2-1 0 0	30.54437471	0.000065	
219	2 3-2 1-1 0	30.55145193	-0.000025	
220	2 3-2 1 0 0	30.55365833	0.001228	-0.000001
221	2 3-2 1 1 0	30.55586474	0.000535	
222	2 3-2 1 2 0	30.55807115	0.000058	
223	2 3-1-1 0 1	30.58544531	0.000040	
224	2 3-1-1 1 1	30.58765171	0.000014	
225	2 3-1 0 0 0	30.59008516	-0.000035	

226	2 3-1 0 1 0	30.59229157	-0.000014	
227	2 3-1 1 0-1	30.59472501	-0.000009	
228	2 3 0-1-1 0	30.62430558	-0.000121	
229	2 3 0-1 0 0	30.62651199	0.006422	-0.000007
230	2 3 0-1 1 0	30.62871839	0.002799	-0.000003
231	2 3 0-1 2 0	30.63092480	0.000307	-0.000001
232	2 3 0 1 0 0	30.63579561	-0.000047	
233	2 3 0 1 1 0	30.63800202	-0.000040	
234	2 3 0 1 2 0	30.64020843	-0.000037	
235	2 3 0 1 3 0	30.64241483	-0.000012	
236	2 3 1-1 0-1	30.66757866	-0.000033	
237	2 3 1-1 1-1	30.66978507	-0.000011	
238	2 3 2-1 0 0	30.70864927	-0.000012	
239	2 3 2-1 1 0	30.71085567	-0.000013	
240	2 4-4 0-1 0	31.01368935	0.000013	
241	2 4-4 2 0 0	31.02517939	0.000020	
242	2 4-4 2 1 0	31.02738579	0.000009	
243	2 4-3 0 0 1	31.05696636	0.000070	
244	2 4-3 0 1 1	31.05917277	0.000030	
245	2 4-2 0-1 0	31.09582663	0.000022	
246	2 4-2 0 0 0	31.09803304	0.001066	
247	2 4-2 0 1 0	31.10023945	0.000458	
248	2 4-2 0 2 0	31.10244585	0.000049	
249	2 4-1 0 0-1	31.13909972	-0.000016	
250	2 4 0-2 0 0	31.17088669	0.000527	
251	2 4 0-2 1 0	31.17309310	0.000229	
252	2 4 0-2 2 0	31.17529951	0.000025	
253	2 4 0 0 0 0	31.18017032	0.001682	-0.000002
254	2 4 0 0 1 0	31.18237673	0.001457	-0.000002
255	2 4 0 0 2 0	31.18458313	0.000472	
256	2 4 0 0 3 0	31.18678954	0.000068	
257	2 5-4 1 0 0	31.56955409	0.000033	
258	2 5-4 1 1 0	31.57176050	0.000014	
259	2 5-3-1 0 1	31.60134107	0.000013	
260	2 5-2-1 0 0	31.64240775	0.000169	
261	2 5-2-1 1 0	31.64461415	0.000072	
262	2 5-2 1 0 0	31.65169137	0.000061	
263	2 5-2 1 1 0	31.65389778	0.000053	
264	2 5-2 1 2 0	31.65610419	0.000017	
265	2 5 0-3 0 0	31.71526140	0.000042	
266	2 5 0-3 1 0	31.71746781	0.000018	
267	2 5 0-1 0 0	31.72454503	0.000322	
268	2 5 0-1 1 0	31.72675143	0.000279	
269	2 5 0-1 2 0	31.72895784	0.000091	
270	2 5 0-1 3 0	31.73116425	0.000013	
271	2 6-4 0 0 0	32.11392880	0.000016	
272	2 6-2-2 0 0	32.18678245	0.000020	
273	2 6-2-2 1 0	32.18898886	0.000009	
274	2 6-2 0 0 0	32.19606608	0.000052	
275	2 6-2 0 1 0	32.19827249	0.000045	
276	2 6-2 0 2 0	32.20047889	0.000014	
277	2 6 0-2 0 0	32.26891973	0.000043	
278	2 6 0-2 1 0	32.27112614	0.000037	
279	2 6 0-2 2 0	32.27333255	0.000012	
280	2 7-2-1 0 0	32.74044079	0.000013	
281	2 7-2-1 1 0	32.74264719	0.000011	

Table 2-30. Tidal harmonics derived from the potential P30.

No.	Arguments Tau	S	H	P	N'P	Angular V. deg./hour	Amplitude (-0.5 =< T =< 0.3) A +	B * T
1	0	0	0	1	-1 0	0.00243541	-0.000013	
2	0	0	0	1	0 0	0.00464181	0.000254	
3	0	0	0	1	1 0	0.00684822	0.000041	
4	0	0	1	0	0 0	0.04106864	0.000004	
5	0	0	2	-1	0 0	0.07749547	0.000047	
6	0	0	2	-1	1 0	0.07970187	0.000007	
7	0	1	-2	0	-1 0	0.46467283	0.000013	
8	0	1	-2	0	0 0	0.46687924	-0.000053	
9	0	1	-2	2	0 0	0.47616287	0.000007	
10	0	1	-1	0	0 1	0.50794984	0.000006	
11	0	1	0	-2	0 0	0.53973289	-0.000019	
12	0	1	0	0	-1 0	0.54681011	-0.000241	
13	0	1	0	0	0 0	0.54901652	0.004660	-0.000001
14	0	1	0	0	1 0	0.55122293	0.000735	
15	0	1	0	0	2 0	0.55342933	-0.000057	
16	0	1	1	0	0 -1	0.59008320	-0.000009	
17	0	1	2	0	1 0	0.63336021	-0.000007	
18	0	1	2	0	2 0	0.63556661	-0.000004	
19	0	2	-3	1	0 1	0.97947089	0.000007	
20	0	2	-2	-1	0 0	1.01125395	-0.000007	
21	0	2	-2	1	-1 0	1.01833117	-0.000008	
22	0	2	-2	1	0 0	1.02053757	0.000148	
23	0	2	-2	1	1 0	1.02274398	0.000023	
24	0	2	-1	-1	0 1	1.05232455	0.000006	
25	0	2	-1	0	0 0	1.05696440	-0.000004	
26	0	2	0	-1	-1 0	1.09118482	-0.000040	
27	0	2	0	-1	0 0	1.09339123	0.000762	
28	0	2	0	-1	1 0	1.09559763	0.000120	
29	0	2	0	-1	2 0	1.09780404	-0.000009	
30	0	2	0	1	0 0	1.10267485	-0.000021	
31	0	2	0	1	1 0	1.10488126	-0.000013	
32	0	2	0	1	2 0	1.10708767	-0.000006	
33	0	2	1	-1	0 -1	1.13445790	-0.000005	
34	0	2	2	-1	0 0	1.17552851	-0.000005	
35	0	2	2	-1	1 0	1.17773491	-0.000004	
36	0	3	-4	2	0 0	1.49205863	0.000003	
37	0	3	-3	0	0 1	1.52384560	0.000008	
38	0	3	-2	0	0 0	1.56491228	0.000128	
39	0	3	-2	0	1 0	1.56711869	0.000020	
40	0	3	0	-2	-1 0	1.63555953	-0.000004	
41	0	3	0	-2	0 0	1.63776593	0.000092	
42	0	3	0	-2	1 0	1.63997234	0.000014	
43	0	3	0	0	0 0	1.64704956	0.000379	
44	0	3	0	0	1 0	1.64925597	0.000236	
45	0	3	0	0	2 0	1.65146237	0.000046	
46	0	4	-4	1	0 0	2.03643333	0.000005	
47	0	4	-2	-1	0 0	2.10928699	0.000028	
48	0	4	-2	-1	1 0	2.11149339	0.000004	
49	0	4	-2	1	0 0	2.11857061	0.000019	

50	0 4-2 1 1 0	2.12077702	0.000012
51	0 4 0-3 0 0	2.18214064	0.000010
52	0 4 0-1 0 0	2.19142427	0.000104
53	0 4 0-1 1 0	2.19363067	0.000065
54	0 4 0-1 2 0	2.19583708	0.000013
55	0 5-2-2 0 0	2.65366169	0.000004
56	0 5-2 0 0 0	2.66294532	0.000018
57	0 5-2 0 1 0	2.66515173	0.000011
58	0 5 0-2 0 0	2.73579897	0.000018
59	0 5 0-2 1 0	2.73800538	0.000011
60	0 6-2-1 0 0	3.20732003	0.000006

Table 2-31. Tidal harmonics derived from the potential P31.

No.	Arguments Tau S H P N'P	Angular V. deg./hour	Amplitude (-0.5 =< T =< 0.3) A + B * T	
1	1-5 2 1-1 0	11.83154221	-0.000012	
2	1-5 2 1 0 0	11.83374861	-0.000031	
3	1-5 0 3 0 0	11.76089496	-0.000014	
4	1-4 0 2-1 0	12.30306326	-0.000040	
5	1-4 0 2 0 0	12.30526967	-0.000100	
6	1-4 2 0-1 0	12.37591691	-0.000040	
7	1-4 2 0 0 0	12.37812332	-0.000101	
8	1-4 3 0 0-1	12.41919000	-0.000007	
9	1-3 0 1-2 0	12.84523156	-0.000018	
10	1-3 0 1-1 0	12.84743797	-0.000229	
11	1-3 0 1 0 0	12.84964437	-0.000580	
12	1-3 0 3 0 0	12.85892800	-0.000014	
13	1-3 1 1 0-1	12.89071105	-0.000007	
14	1-3 2-1-1 0	12.92029162	-0.000043	
15	1-3 2-1 0 0	12.92249803	-0.000108	
16	1-3 2 1 0 0	12.93178165	-0.000040	
17	1-3 4-1 0 0	13.00463531	-0.000008	
18	1-2-2 2 0 0	13.32116543	0.000013	
19	1-2-1 0 0 1	13.35295240	0.000011	
20	1-2 0 0-2 0	13.38960627	-0.000065	
21	1-2 0 0-1 0	13.39181267	-0.000836	
22	1-2 0 0 0 0	13.39401908	-0.002112	0.000002
23	1-2 0 2-1 0	13.40109630	0.000019	
24	1-2 0 2 0 0	13.40330271	-0.000130	
25	1-2 0 2 1 0	13.40550911	0.000016	
26	1-2 1 0 0-1	13.43508576	-0.000012	
27	1-2 2 0-1 0	13.47394995	0.000027	
28	1-2 2 0 0 0	13.47615636	-0.000181	
29	1-2 3 0 0-1	13.51722304	-0.000012	
30	1-1-2 1-1 0	13.86333373	0.000015	
31	1-1-2 1 0 0	13.86554013	0.000029	
32	1-1-1 1 0 1	13.90661074	0.000007	
33	1-1 0-1-2 0	13.93398097	0.000008	
34	1-1 0-1-1 0	13.93618738	0.000047	
35	1-1 0-1 0 0	13.93839379	0.000119	
36	1-1 0 1-1 0	13.94547101	0.000160	
37	1-1 0 1 0 0	13.94767741	-0.001080	
38	1-1 0 1 1 0	13.94988382	0.000141	
39	1-1 1 1 0-1	13.98874409	-0.000008	
40	1-1 2-1-1 0	14.01832466	0.000031	
41	1-1 2-1 0 0	14.02053107	-0.000210	
42	1-1 2-1 1 0	14.02273747	0.000029	
43	1-1 3-1 0-1	14.06159775	-0.000009	
44	1 0-2 0-1 0	14.40770843	0.000025	
45	1 0-1 0 0 1	14.45098544	0.000012	
46	1 0 0 0-2 0	14.48763931	-0.000030	
47	1 0 0 0-1 0	14.48984571	0.000977	-0.000001
48	1 0 0 0 0 0	14.49205212	-0.006608	-0.000005

49	1 0 0 0 1 0	14.49425853	0.000855	-0.000001
50	1 0 0 0 2 0	14.49646493	-0.000013	
51	1 0 0 2 0 0	14.50133575	-0.000010	
52	1 0 1 0 0-1	14.53311880	-0.000010	
53	1 0 2-2 0 0	14.56490577	-0.000010	
54	1 0 2 0 0 0	14.57418940	-0.000027	
55	1 0 2 0 1 0	14.57639581	0.000017	
56	1 1-2 1-1 0	14.96136677	0.000009	
57	1 1-2 1 0 0	14.96357317	-0.000067	
58	1 1-2 1 1 0	14.96577958	0.000009	
59	1 1 0-1-1 0	15.03422042	0.000054	
60	1 1 0-1 0 0	15.03642683	-0.000360	
61	1 1 0-1 1 0	15.03863323	0.000046	
62	1 1 0 1 0 0	15.04571045	-0.000131	
63	1 1 0 1 1 0	15.04791686	-0.000054	
64	1 1 2-1 0 0	15.11856411	-0.000024	
65	1 1 2-1 1 0	15.12077051	-0.000009	
66	1 2-2 0-1 0	15.50574147	-0.000017	
67	1 2-2 0 0 0	15.50794788	-0.000076	
68	1 2-2 0 1 0	15.51015429	0.000009	
69	1 2 0-2 0 0	15.58080153	-0.000027	
70	1 2 0 0-1 0	15.58787875	0.000078	
71	1 2 0 0 0 0	15.59008516	-0.002412	0.000002
72	1 2 0 0 1 0	15.59229157	-0.000977	
73	1 2 0 0 2 0	15.59449797	-0.000081	
74	1 3-2-1 0 0	16.05232259	-0.000010	
75	1 3-2 1 0 0	16.06160621	-0.000077	
76	1 3-2 1 1 0	16.06381262	-0.000031	
77	1 3 0-1-1 0	16.13225346	0.000013	
78	1 3 0-1 0 0	16.13445987	-0.000394	
79	1 3 0-1 1 0	16.13666627	-0.000159	
80	1 3 0-1 2 0	16.13887268	-0.000013	
81	1 4-2 0 0 0	16.60598092	-0.000066	
82	1 4-2 0 1 0	16.60818733	-0.000027	
83	1 4 0-2 0 0	16.67883457	-0.000048	
84	1 4 0-2 1 0	16.68104098	-0.000019	
85	1 4 0 0 0 0	16.68811820	-0.000091	
86	1 4 0 0 1 0	16.69032461	-0.000077	
87	1 4 0 0 2 0	16.69253101	-0.000024	
88	1 5-2-1 0 0	17.15035563	-0.000015	
89	1 5 0-1 0 0	17.23249291	-0.000025	
90	1 5 0-1 1 0	17.23469931	-0.000021	
91	1 5 0-1 2 0	17.23690572	-0.000006	

Table 2-32. Tidal harmonics derived from the potential P32.

No.	Arguments Tau S H P N' P	Angular V. deg./hour	Amplitude (-0.5 =< T =< 0.3) A	+ B * T
1	2-5 2 2 0 0	26.33044255	-0.000017	
2	2-5 4 0 0 0	26.40329620	-0.000009	
3	2-4 0 3 0 0	26.80196360	-0.000038	
4	2-4 2 1-1 0	26.87261085	-0.000014	
5	2-4 2 1 0 0	26.87481725	-0.000082	
6	2-4 4-1 0 0	26.94767091	-0.000016	
7	2-3 0 2-1 0	27.34413190	-0.000046	
8	2-3 0 2 0 0	27.34633831	-0.000270	
9	2-3 2 0-1 0	27.41698555	-0.000046	
10	2-3 2 0 0 0	27.41919196	-0.000271	
11	2-3 3 0 0-1	27.46025864	-0.000018	
12	2-3 4-2 0 0	27.49204561	-0.000010	
13	2-2-2 3 0 0	27.81785936	0.000008	
14	2-2-1 1 0 1	27.84964634	0.000016	
15	2-2 0 1-2 0	27.88630020	0.000014	
16	2-2 0 1-1 0	27.88850661	-0.000265	
17	2-2 0 1 0 0	27.89071301	-0.001562	
18	2-2 0 3 0 0	27.89999664	0.000011	
19	2-2 1 0 0 0	27.92713984	0.000008	
20	2-2 1 1 0-1	27.93177969	-0.000016	
21	2-2 2-1-1 0	27.96136026	-0.000050	
22	2-2 2-1 0 0	27.96356667	-0.000292	
23	2-2 2 1 0 0	27.97285029	0.000032	
24	2-2 3-1 0-1	28.00463335	-0.000014	
25	2-2 4-1 0 0	28.04570395	0.000007	
26	2-1-2 2 0 0	28.36223407	0.000035	
27	2-1-1 0 0 1	28.39402104	0.000029	
28	2-1 0 0-2 0	28.43067491	0.000052	
29	2-1 0 0-1 0	28.43288131	-0.000967	
30	2-1 0 0 0 0	28.43508772	-0.005691	0.000002
31	2-1 0 2 0 0	28.44437135	0.000103	
32	2-1 0 2 1 0	28.44657775	0.000018	
33	2-1 1 0 0-1	28.47615440	-0.000024	
34	2-1 2-2 0 0	28.50794137	0.000012	
35	2-1 2 0-1 0	28.51501859	-0.000008	
36	2-1 2 0 0 0	28.51722500	0.000144	
37	2-1 3 0 0-1	28.55829168	0.000010	
38	2 0-2 1-1 0	28.90440237	0.000017	
39	2 0-2 1 0 0	28.90660877	0.000079	
40	2 0 0-1-1 0	28.97725602	0.000055	
41	2 0 0-1 0 0	28.97946243	0.000322	
42	2 0 0 1-1 0	28.98653965	-0.000051	
43	2 0 0 1 0 0	28.98874605	0.000858	
44	2 0 0 1 1 0	28.99095246	0.000163	
45	2 0 0 1 2 0	28.99315887	-0.000007	
46	2 0 1 1 0-1	29.02981273	0.000007	
47	2 0 2-1-1 0	29.05939330	-0.000010	
48	2 0 2-1 0 0	29.06159971	0.000167	

49	2 0 2-1 1 0	29.06380611	0.000034	
50	2 0 3-1 0-1	29.10266639	0.000008	
51	2 1-2 0-1 0	29.44877707	0.000028	
52	2 1-1 0 0 1	29.49205408	-0.000010	
53	2 1 0 0-1 0	29.53091435	-0.000311	
54	2 1 0 0 0 0	29.53312076	0.005250	-0.000001
55	2 1 0 0 1 0	29.53532717	0.000989	
56	2 1 0 0 2 0	29.53753357	-0.000035	
57	2 1 1 0 0-1	29.57418744	0.000007	
58	2 1 2-2 0 0	29.60597441	0.000008	
59	2 2-3 0 0 0	29.95893136	-0.000007	
60	2 2-2 1 0 0	30.00464181	0.000053	
61	2 2-2 1 1 0	30.00684822	0.000010	
62	2 2 0-1-1 0	30.07528906	-0.000017	
63	2 2 0-1 0 0	30.07749547	0.000286	
64	2 2 0-1 1 0	30.07970187	0.000054	
65	2 2 0 1 0 0	30.08677909	0.000026	
66	2 2 0 1 1 0	30.08898550	0.000017	
67	2 3-2 0 0 0	30.54901652	0.000060	
68	2 3-2 0 1 0	30.55122293	0.000011	
69	2 3 0-2 0 0	30.62187017	0.000022	
70	2 3 0 0-1 0	30.62894739	-0.000011	
71	2 3 0 0 0 0	30.63115380	0.000484	
72	2 3 0 0 1 0	30.63336021	0.000311	
73	2 3 0 0 2 0	30.63556661	0.000064	
74	2 4-2-1 0 0	31.09339123	0.000008	
75	2 4-2 1 0 0	31.10267485	0.000015	
76	2 4-2 1 1 0	31.10488126	0.000010	
77	2 4 0-1 0 0	31.17552851	0.000079	
78	2 4 0-1 1 0	31.17773491	0.000051	
79	2 4 0-1 2 0	31.17994132	0.000011	
80	2 5-2 0 0 0	31.64704956	0.000013	
81	2 5-2 0 1 0	31.64925597	0.000008	
82	2 5 0-2 0 0	31.71990321	0.000009	
83	2 5 0 0 0 0	31.72918684	0.000010	
84	2 5 0 0 1 0	31.73139325	0.000011	

Table 2-33. Tidal harmonics derived from the potential P33.

No.	Arguments Tau	S	H	P	N'P	Angular V. deg./hour	Amplitude (-0.5 =< T =< 0.3) A	+	B * T
1	3-4	0	4	0	0	41.29865754	-0.000010		
2	3-4	2	2	0	0	41.37151119	-0.000035		
3	3-4	4	0	0	0	41.44436484	-0.000019		
4	3-3	0	3	0	0	41.84303224	-0.000079		
5	3-3	2	1	-1	0	41.91367949	0.000010		
6	3-3	2	1	0	0	41.91588589	-0.000171		
7	3-3	3	1	0	-1	41.95695257	-0.000013		
8	3-3	4	-1	0	0	41.98873955	-0.000033		
9	3-2	-1	2	0	1	42.34634027	0.000009		
10	3-2	0	2	-1	0	42.38520054	0.000032		
11	3-2	0	2	0	0	42.38740695	-0.000565		
12	3-2	1	0	0	1	42.41919392	0.000009		
13	3-2	1	2	0	-1	42.42847363	-0.000010		
14	3-2	2	0	-1	0	42.45805419	0.000032		
15	3-2	2	0	0	0	42.46026060	-0.000567		
16	3-2	3	0	0	-1	42.50132728	-0.000038		
17	3-2	4	-2	0	0	42.53311425	-0.000020		
18	3-1	-2	3	0	0	42.85892800	0.000017		
19	3-1	-1	1	0	1	42.89071498	0.000033		
20	3-1	0	-1	-2	0	42.91808521	0.000012		
21	3-1	0	1	-1	0	42.92957525	0.000183		
22	3-1	0	1	0	0	42.93178165	-0.003260		-0.000001
23	3-1	1	-1	0	1	42.96356863	0.000007		
24	3-1	1	0	0	0	42.96820848	0.000017		
25	3-1	1	1	0	-1	42.97284833	-0.000035		
26	3-1	2	-1	-1	0	43.00242890	0.000034		
27	3-1	2	-1	0	0	43.00463531	-0.000609		
28	3-1	2	1	0	0	43.01391893	-0.000009		
29	3-1	3	-1	0	-1	43.04570199	-0.000029		
30	3	0	-2	2	0	43.40330271	0.000073		
31	3	0	-2	0	-2	43.38960627	0.000007		
32	3	0	-1	0	1	43.43508968	0.000061		
33	3	0	0	-2	0	43.47174355	-0.000015		
34	3	0	0	-1	0	43.47394995	0.000665		
35	3	0	0	0	0	43.47615636	-0.011881		-0.000002
36	3	0	0	2	0	43.48543999	-0.000030		
37	3	0	0	2	1	43.48764639	-0.000013		
38	3	0	1	0	-1	43.51722304	-0.000055		
39	3	0	2	-2	0	43.54901001	0.000026		
40	3	0	2	0	0	43.55829364	-0.000042		
41	3	1	-3	1	0	43.90661074	0.000008		
42	3	1	-2	1	-1	43.94547101	-0.000012		
43	3	1	-2	1	0	43.94767741	0.000166		
44	3	1	0	-1	-1	44.01832466	-0.000038		
45	3	1	0	-1	0	44.02053107	0.000673		
46	3	1	0	1	-1	44.02760829	0.000010		
47	3	1	0	1	0	44.02981469	-0.000253		
48	3	1	0	1	1	44.03202110	-0.000112		

49	3 1 0 1 2 0	44.03422751	-0.000014
50	3 1 2-1 0 0	44.10266835	-0.000049
51	3 1 2-1 1 0	44.10487475	-0.000023
52	3 2-2 0-1 0	44.48984571	-0.000019
53	3 2 0 0-1 0	44.57198299	0.000058
54	3 2 0 0 0 0	44.57418940	-0.001548
55	3 2 0 0 1 0	44.57639581	-0.000679
56	3 2 0 0 2 0	44.57860221	-0.000074
57	3 3-3 0 0 0	45.00000000	-0.000014
58	3 3-2 1 0 0	45.04571045	-0.000016
59	3 3-2 1 1 0	45.04791686	-0.000007
60	3 3 0-1 0 0	45.11856411	-0.000084
61	3 3 0-1 1 0	45.12077051	-0.000037
62	3 4-2 0 0 0	45.59008516	-0.000018
63	3 4-2 0 1 0	45.59229157	-0.000008
64	3 4 0 0 0 0	45.67222244	-0.000067
65	3 4 0 0 1 0	45.67442885	-0.000058
66	3 4 0 0 2 0	45.67663525	-0.000019
67	3 5 0-1 0 0	46.21659715	-0.000011
68	3 5 0-1 1 0	46.21880355	-0.000010

Table 2-40. Tidal harmonics derived from the potential P40.

No.	Arguments Tau S H P N'P	Angular V. deg./hour	Amplitude
1	0 0 0 0 0 0	0.00000000	0.000043
2	0 0 0 0 1 0	0.00220641	-0.000033
3	0 1 0-1-1 0	0.54216830	-0.000004
4	0 1 0-1 0 0	0.54437471	0.000012
5	0 1 0-1 1 0	0.54658111	-0.000004
6	0 2 0 0 0 0	1.09803304	0.000086
7	0 2 0 0 1 0	1.10023945	0.000032
8	0 3 0-1 0 0	1.64240775	0.000021
9	0 3 0-1 1 0	1.64461415	0.000008
10	0 4 0 0 0 0	2.19606608	0.000005

Table 2-41. Tidal harmonics derived from the potential P41.

No.	Arguments Tau	S	H	P	N'P	Angular V. deg./hour	Amplitude
1	1	-3	0	0	-1 0	12.84279615	0.000007
2	1	-3	0	0	0 0	12.84500256	0.000012
3	1	-2	0	1	0 0	13.39866089	0.000024
4	1	-2	2	-1	0 0	13.47151455	0.000005
5	1	-1	0	0	-1 0	13.94082919	0.000011
6	1	-1	0	0	0 0	13.94303560	0.000098
7	1	-1	0	0	1 0	13.94524201	-0.000008
8	1	0	0	1	0 0	14.49669393	-0.000013
9	1	1	0	0	-1 0	15.03886223	0.000010
10	1	1	0	0	0 0	15.04106864	-0.000094
11	1	1	0	0	1 0	15.04327505	-0.000011
12	1	2	0	-1	0 0	15.58544335	-0.000013
13	1	3	0	0	0 0	16.13910168	-0.000017
14	1	3	0	0	1 0	16.14130809	-0.000010

Table 2-42. Tidal harmonics derived from the potential P42.

No.	Arguments Tau	S	H	P	N'P	Angular V. deg./hour	Amplitude
1	2	-3	0	1	-1 0	27.33949009	0.000005
2	2	-3	0	1	0 0	27.34169649	0.000013
3	2	-2	0	0	-1 0	27.88386479	0.000014
4	2	-2	0	0	0 0	27.88607120	0.000036
5	2	-1	0	1	0 0	28.43972953	0.000015
6	2	0	0	0	-1 0	28.98189783	-0.000016
7	2	0	0	0	0 0	28.98410424	0.000062
8	2	0	0	0	1 0	28.98631065	-0.000014
9	2	1	0	1	0 0	29.53776257	0.000006
10	2	2	0	0	0 0	30.08213728	0.000042
11	2	2	0	0	1 0	30.08434369	0.000016
12	2	3	0	-1	0 0	30.62651199	0.000006

Table 2-43. Tidal harmonics derived from the potential P43.

No.	Arguments Tau	S	H	P	N'P	Angular V. deg./hour	Amplitude
1	3	-3	0	2	0	41.83839043	0.000007
2	3	-3	2	0	0	41.91124408	0.000006
3	3	-2	0	1	-1	42.38055873	0.000005
4	3	-2	0	1	0	42.38276513	0.000031
5	3	-2	2	-1	0	42.45561879	0.000006
6	3	-1	0	0	-1	42.92493343	0.000013
7	3	-1	0	0	0	42.92713984	0.000088
8	3	0	0	-1	0	43.47151455	-0.000007
9	3	0	0	1	0	43.48079817	-0.000019
10	3	1	0	0	-1	44.02296647	0.000007
11	3	1	0	0	0	44.02517288	-0.000077
12	3	1	0	0	1	44.02737929	-0.000014
13	3	3	0	0	0	45.12320592	-0.000011
14	3	3	0	0	1	45.12541233	-0.000007

Table 2-44. Tidal harmonics derived from the potential P44.

No.	Arguments Tau	S	H	P	N'P	Angular V. deg./hour	Amplitude
1	4	-2	0	2	0	56.87945907	0.000012
2	4	-2	2	0	0	56.95231272	0.000011
3	4	-1	0	1	0	57.42383377	0.000058
4	4	-1	2	-1	0	57.49668743	0.000011
5	4	0	0	0	-1	57.96600207	-0.000012
6	4	0	0	0	0	57.96820848	0.000162
7	4	1	0	-1	0	58.51258319	-0.000014
8	4	1	0	1	0	58.52186681	0.000007
9	4	2	0	0	0	59.06624152	0.000028
10	4	2	0	0	1	59.06844793	0.000013

Table 3. Comparison of Xi's and Tamura's developments around O_1 constituent. Columns shown with - have smaller amplitudes than Tamura's threshold level.

epoch	Xi 1900	Tamura 1900(extrapolated)	
Argument	$\times 10^{-6}$	$\times 10^{-6}$	
1-1-1 0-1 1	-15	-154	
1-1-1 0 0 1	-130	-1298	
1-1-1 1 0 0	6	57	
1-1-1 2 0-1 *	1	-	(-9)
1-1-1 2 0 1 *	2	33	(24)
1-1 0-2-2 0	1	14	
1-1 0 0-3 0	2	21	
1-1 0 0-2 0	-218	-2181	
1-1 0 0-1 0	7103	71061	
1-1 0 0 0 0	37698	376941	
1-1 0 0 1 0	-	15	
1-1 0 2-1 0	7	70	
1-1 0 2 0 0	-242	-2431	
1-1 0 2 1 0	-40	-396	
1-1 0 2 2 0	1	15	
1-1 1-2 0 1	-1	-	(5)
1-1 1-1 0 0	-1	-14	
1-1 1 0-1-1	13	119	
1-1 1 0 0-1 *	115	1143	
1-1 1 0 0 1 *	5	55	
1-1 1 0 1 1	-4	-35	
1-1 1 1 0 0	3	25	
1-1 1 1 1 0	1	-	(4)
1-1 1 2 0-1	-3	-30	
1-1 1 2 1-1	-1	-	(-6)

* : paired terms

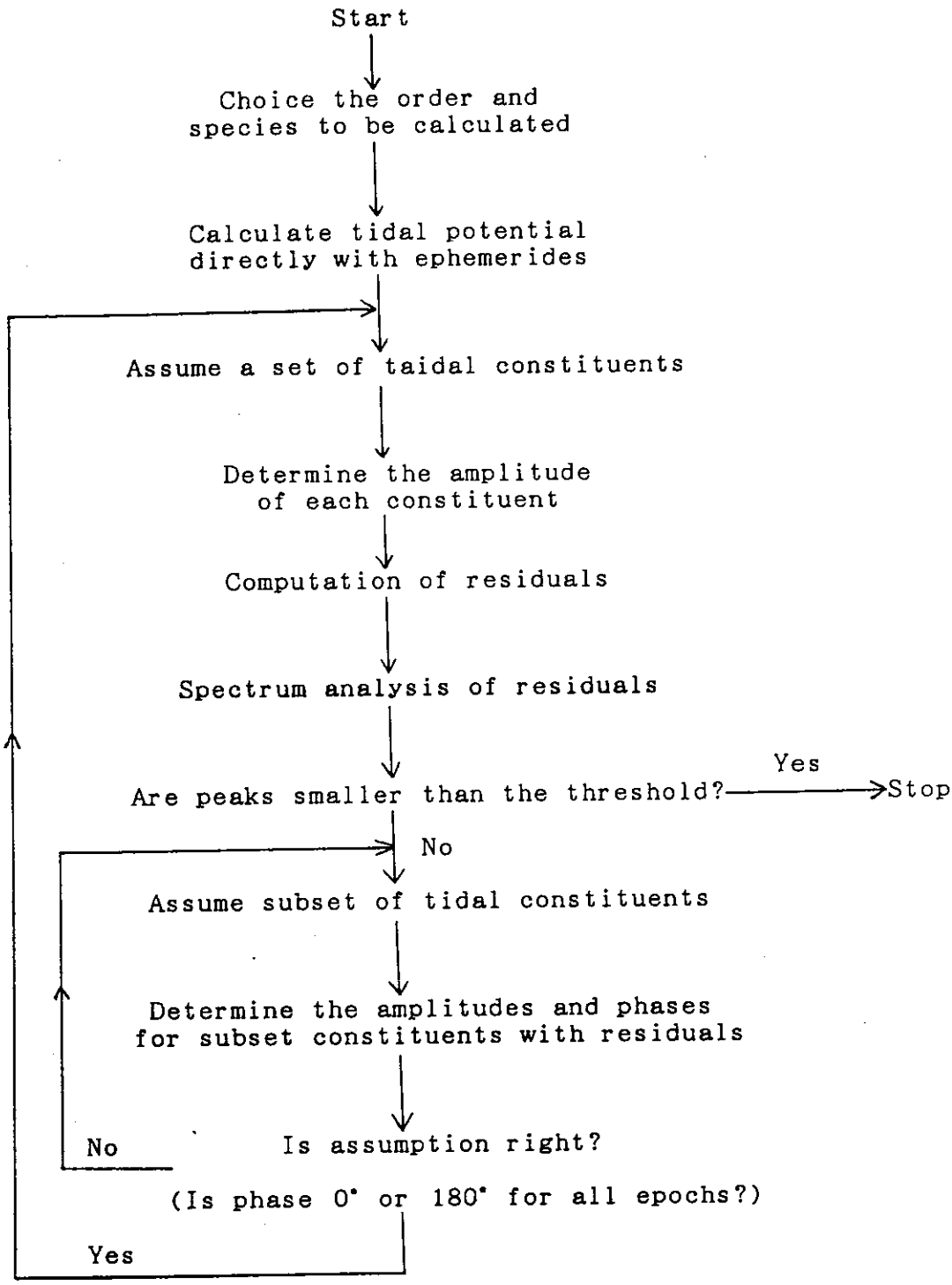

Figure 1. Flow chart of the harmonic development of the tide-generating potential by numerical method.

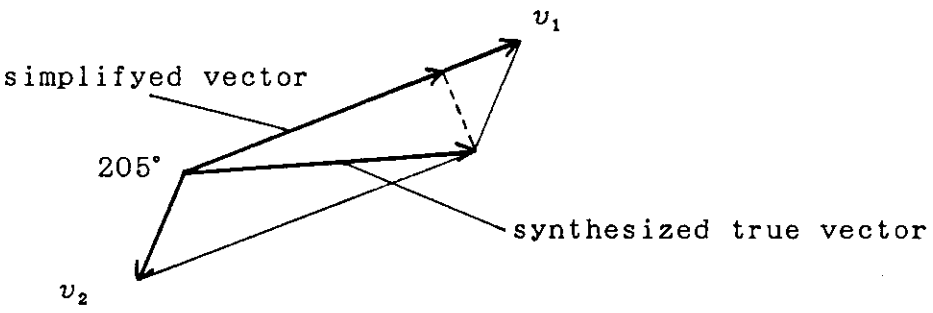

Figure 2. Synthesis of paired constituents whose angular velocities differ only by $2f_6$.

Appendix How to Calculate the Tidal Potential with the Harmonic Tables.

Following sequence, the tide-generating potential P_{nm} are calculated.

$$CV = \frac{3}{4}\mu GE\left(\frac{\sin \Pi}{3600} \cdot \frac{\pi}{180} \right)^3 \frac{1}{Re^2} \qquad \text{(A-1)}$$

$$Z_n = CV \cdot r\left(\frac{r}{Re}\right)^{n-1} \qquad for\ n = 2, 3, 4 \qquad \text{(A-2)}$$

$$P_{nm} = \sum^{i} amp_i \frac{g_{nm}(\phi)}{\max|g_{nm}(\phi)|} Z_n \cdot \cos(\omega_i \cdot t + \delta_{nm}) \quad for\ m = 0, 1, \cdots, n \qquad \text{(A-3)}$$

where r and ϕ is the geocentric radius and latitude of a site respectively. δ_{nm} is 0° if $n+m$ is even and -90° if $n+m$ is odd. The values amp_i and ω_i are given in the tables. The functions $g_{nm}(\phi)$ express the geographical coefficients. $\max|g_{nm}(\phi)|$ ($= \Gamma_{nm}$) are called Doodson's normalization factors. They are denoted as

$$\left.\begin{aligned}
g_{20}(\phi) &= 1-3\sin^2\phi, & g_{21}(\phi) &= \sin 2\phi, \\
g_{22}(\phi) &= \cos^2\phi, & g_{30}(\phi) &= \sin\phi(3-5\sin^2\phi), \\
g_{31}(\phi) &= \cos\phi(1-5\sin^2\phi), & g_{32}(\phi) &= \sin\phi\cdot\cos^2\phi, \\
g_{33}(\phi) &= \cos^3\phi, & g_{40}(\phi) &= 3-30\sin^2\phi+35\sin^4\phi, \\
g_{41}(\phi) &= \sin 2\phi(3-7\sin^2\phi), & g_{42}(\phi) &= \cos^2\phi(1-7\sin^2\phi), \\
g_{43}(\phi) &= \sin\phi\cdot\cos^3\phi, & g_{44}(\phi) &= \cos^4\phi.
\end{aligned}\right\} \text{(A-4)}$$

$$
\left.
\begin{aligned}
&\Gamma_{20} = 2, \qquad \Gamma_{21} = 1, \qquad \Gamma_{22} = 1, \\
&\Gamma_{30} = 2, \qquad \Gamma_{31} = \frac{16}{3\sqrt{15}}, \\
&\Gamma_{32} = \frac{2}{3\sqrt{3}}, \qquad \Gamma_{33} = 1, \\
&\Gamma_{40} = 8, \qquad \Gamma_{41} = \frac{(3+\sqrt{393})\sqrt{390+2\sqrt{393}}}{224}, \\
&\Gamma_{42} = \frac{9}{7}, \qquad \Gamma_{43} = \frac{3\sqrt{3}}{16}, \qquad \Gamma_{44} = 1.
\end{aligned}
\right\} \quad \text{(A-5)}
$$

Doodson adopted nomalization factor $\Gamma_{30} = 2/\sqrt{5}$ in mistake. This scale is also adopted in this development to compare with his schedules.

If one wants to calculate the three component tidal accelerations in stead of potential, he can get them by differentiating the potential P_{nm}. The acceleration toward anti-geocentric direction is calculated by multiplying n/r to P_{nm}. The north direction component (not horizontal direction on ellipsoidal earth but tangential to a sphere of radius r) is obtained by differentiating the numerator $g_{nm}(\phi)$ in the equation (A-3) by geocentric latitude ϕ and multiplying $1/r$ to (A-3). The east one also calculated by adding 90° to the argument of cosine and multiplying $m/(r\cdot\cos\phi)$ to P_{nm}.

Reference

Tsukamoto, H., 1980. A note on earth tides, part 1. On theoretical calculation of the tide-generating potential. private comunication (written in Japanese, the title is translated in English by the author).