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Minoru ODAMAKI

Harmonic Analysis Trial based on the Tidal Constituents list by TWG/IHO.

1. Introduction

In Japan, traditional 60 tidal constituents are used for tidal prediction of the major ports, which short period tides are derived from the 1 year harmonic analysis and long period tides are from several years.

Recently, tidal heights are shown in real-time base through the website of our JHOD, JMA and etc. In the site, the graphs of observed and predicted tidal heights and their deviation are shown. Higher harmonics are remarked in the deviation graph. Additionally, semidiurnal tides in some place are perhaps varied by season. The "standard tidal constituents list" by TWG/IHO includes the higher harmonic of M7 to M12, and M2A and M2B of seasonal change of major M2. Then we tried to apply the tidal constituents list to the harmonic analysis for several tidal records.

Some constituents in the list have almost same angular speed and unable to separate for several years, so we have selected 147 tidal constituents considering the traditionally well-known references.

2. Basic Tidal Equation and Harmonic Analysis by the direct Least Square Method.

Recently, tidal height are digitally observed by digital tidal gauge or electronic equipments, and recorded in shorter period such as 30 sec. Some tidal records are long continued over than 1year. We consider the trial applying the data in 6 min. interval for several years (2006-2009).

Basic tidal equation is same as traditional one;

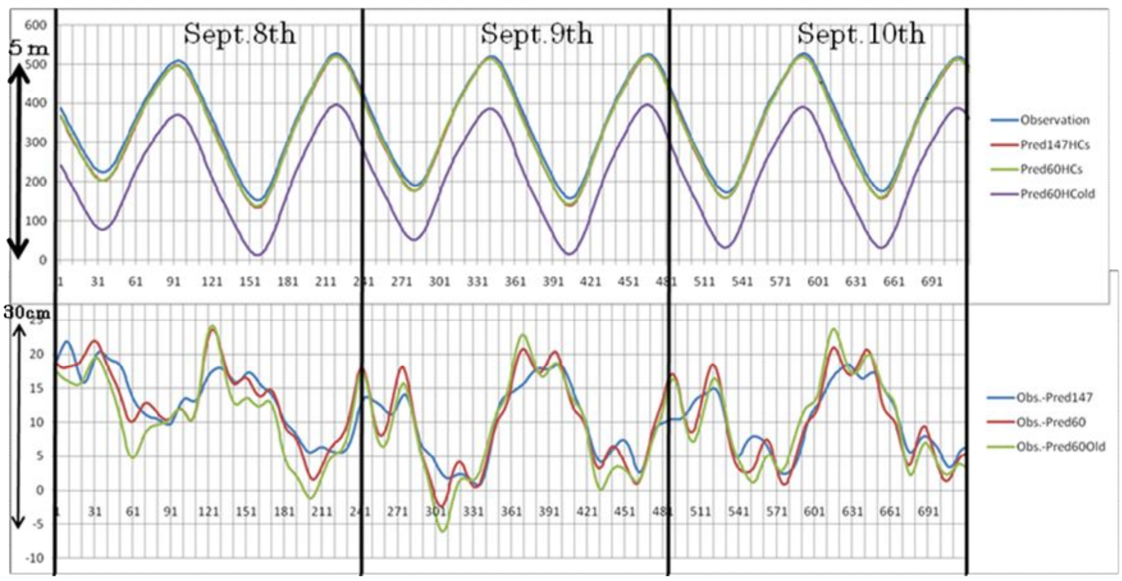
$$H(t) = \sum fi \cdot Ai \cdot \cos \{(V_0+ui) + \sigma i \cdot t - \kappa i\} = \sum \{ACi \cdot \cos \sigma i \cdot t + ASi \cdot \cos \sigma i \cdot t\}$$

fi,ui : Astronomical factors, $V_0 i$: Astronomical arguments, σi : Angular speed,
Ai・κi : amplitude, phase lag. ACi , ASi : cos, sin components
Suffix i = tidal constituents =60, or 147 (M2A,M2B,,, and M7,M8,,, M12)
fi,ui : varied with (t) , which was assumed constant during the analysis period in traditional harmonic analysis.
(t) : time interval, 1 hour → 6min.

3. Results

Applying to the tidal height data of Hiroshima in 6min. interval for 4 years, 2006 - 2009 (RDMDB/ NEAR-GOOS by JODC), (1) 147 and (2) 60 harmonic constants in the Table 1 are derived using the least square method directly. The previous harmonic constants (3) 60 were also listed in the Table, which were calculated by the T.I. method except the long period tides Sa and Ssa. In order to check each reliability of the HCs, tidal predictions are calculated for 1 year, 2010, using (1) , (2) and (3). Comparing with the observed data of 2010, the correlation coefficients are (1) 0.9944, (2) 0.9942, and (3) 0.9940, and the standard deviations are (1) 9.13, (2) 9.23, and (3) 9.42 cm, respectively. Each amplitude and phase lag of major tidal constituent is marvelously same. Minor constituents added in (1) 147, are almost small except MA2 1.3cm and 2MO5 1.1cm. This result means each tidal prediction is not so different in a particular day as shown in Figure 1, but the each deviation from the observation is clearly different that (1) 147 HCs is able to predict the higher harmonic constituents compared to (2) and (3) 60 HCs.

Figure 1. Comparison of Tidal Predictions, Hiroshima 2010（Obs.-Pred.).



4. Conclusion

This trial result shows the prediction by ordinary 60 HCs is practically enough because the correlation of Obs. and Pre. is more than 0.99 and S.D is less than 10cm.

But for the more precise prediction, the higher harmonics of shallow water tides and seasonal fluctuation of major constituents such as MA2 for M2, should be included. In other trial case, the reliability of (1) 147 HCs is not better than (2) or (3) 60 HCs, in which reason the several day period fluctuation, perhaps non-tidal, may affect the tidal height. In conclusion, in order to improve the reliability of tidal prediction, considering the non-tidal components to separate well with tidal fluctuation, the proper tidal constituents set should be used representing well higher harmonics and fluctuation of major constituents.

Reference

1) Standard Development of Tide Generating Potential.

IHB Circular Letter No.4-H, 1954, (Reprint from IHR May 1954), SP No.40.

The Harmonic Development of the Tide-Generating Potential, by A.T. Doodson 1921.

60 Tidal constituents list：

"The Analysis of Tidal Observations",

by A.T.Doodson, Publication of R.S. of London 1928

67 Tidal Constituents list：

"The Admiralty Method of Long Period Observations for Hamonic Tidal Analysis", Admiralty Tidal Handbook No.1, by the Hydrographer of the Navy, N.P. 122(1)

147 Tidal Constituents list：

Selected from " Standard list of tidal constituents" by TG/IHO.

<u>(unable to apply the whole constituents.*)</u>

Solution		Hiroshima		Solutio Hiroshima			広島		
		147			60			60	
	Corre.	0.9944			0.994			0.994	
Obs-Pre.	S.D.	9.13			9.23			9.42	
	Z0	325.1		Z0	325.1		Z0	200	
1	Sa	17.1	144.6	Sa	17.1	144.6	Sa	18.1	152.7
2	Ssa	1.1	94.4	Ssa	1.1	94.4	Ssa	1	336.9
3	Mm	0.9	96	Mm	0.9	96	Mm	1.8	238.9
4	MSf	0.8	293.8	MSf	0.8	293.8	MSf	0.8	267.7
5	Mf	1.1	92.1	Mf	1.1	92.1	Mf	1.2	206
6	2Q1	0.5	185.4	2Q1	0.5	185.4	2Q1	0.7	151.1
7	sigma1	1.1	245.1	sigma1	1.1	245.1	σ1	0.8	239.5
8	Q1	4.6	182.8	Q1	4.6	182.8	Q1	4.4	187.1
9	rho1	1	162.9	rho1	1	162.9	ρ1	1	167
10	O1	22.8	194.9	O1	22.8	194.9	O1	22.5	194.7
11	MP1	2.1	284.5	MP1	2.1	284.4	MP1	1.1	305.2
12	M1	1.1	213.4	M1	1.1	213.4	M1	1.5	233.1
13	Khai1	0.2	161.5	Khai1	0.2	161.6	χ1	0.5	194.6
14	pai1	0.7	236.1	pai1	0.7	236	π1	0.7	223.8
15	P1	9.3	218.8	P1	9.3	218.8	P1	9.5	220.3
16	S1	1	100.2	S1	1	100.2	S1	1.4	117.2
17	K1	31.3	216.9	K1	31.3	216.9	K1	31.2	217.1
18	psai1	0.5	250.8	psai1	0.5	250.7	ψ1	0.4	179.4
19	fai1	0.4	172.2	fai1	0.4	172.3	φ1	0.5	189.4
20	theta1	0.4	253.8	theta1	0.4	253.8	θ1	0.3	262.2
21	J1	1.7	256.3	J1	1.7	256.3	J1	1.6	257.7
22	SO1	1.5	5.6	SO1	1.5	5.6	SO1	1.7	0
23	OO1	1.2	283.9	OO1	1.2	283.9	OO1	0.9	321.5
24	OQ2	0.2	16.6	OQ2	0.2	17	OQ2	0.5	226.5
25	MNS2	0.5	180	MNS2	0.5	179.5	MNS2	0.4	44.8
26	2MK2	0.5	142.5						
27	2N2	2.1	266.7	2N2	2.1	267	2N2	2.3	250.6
28	myu2	0.9	18.7	myu2	0.9	18.5	μ2	0.4	80.9
29	SNK2	0.3	3.7						
30	NA2	0.3	27.9						
31	N2	17.8	265.9	N2	17.8	266	N2	17.8	266.3
32	NB2	0.6	202						
33	nyu2	3.8	265.7	nyu2	3.9	265.7	ν2	3.5	276.2
34	OP2	0.5	69	OP2	0.5	69.5	OP2	0.7	187.9
35	MA2	1.3	200.5						
36	M2	102	277.8	M2	102	277.8	M2	102	278.3
37	MB2	0.3	324.9						
38	MKS2	0.8	122.8	MKS2	0.8	122.3	MKS2	0.8	89.9
39	lamda2	1.6	297.7	lamda2	1.6	297.8	λ2	1.9	308.6
40	L2	3.6	297.6	L2	3.6	297.6	L2	3.4	299.1
41	2SK2	0.3	42						
42	T2	2.6	302.2	T2	2.5	302.3	T2	2.8	308.5
43	S2	42.4	307.8	S2	42.4	307.8	S2	41.9	307.8
44	R2	0.4	306.3	R2	0.5	305.7	R2	0.7	315.5
45	K2	12.2	303.4	K2	12.2	303.4	K2	12.1	305.1
46	MSN2	0.6	83.7	MSN2	0.6	84.4	MSN2	1	147.3
47	KJ2	0.7	129	KJ2	0.7	129	KJ2	0.6	136.4
48	2SM2	1.5	179	2SM2	1.5	179	2SM2	1.4	168.1
49	MQ3	0.1	143.6	MQ3	0.1	144.3	MO3	0.1	157.1
50	MO3	0.3	150.9						
51	2MP3	0.3	204.5						
＊52	MA3	0	143.9						

	53	M3	0.4	342.9	M3	0.4	342.4	M3	0.5	2.1
*	54	MB3	0.1	233.5						
	55	MP3	0.4	224.9	MP3	0.4	225.2	SO3	0.3	64.7
	56	MK3	0.3	181.4	MK3	0.3	181.9	MK3	0.1	29.8
	57	2MQ3	0.1	238.8						
	58	SK3	0.4	226	SK3	0.4	226.1	SK3	0.3	210.1
	59	3MK4	0.1	289.7						
	60	3MS4	0.2	320.5						
	61	MN4	0.5	28.4	MN4	0.5	28.4	MN4	0.6	34.9
	62	Mnyu4	0.1	123						
	63	2MSK4	0.1	312.7						
	64	MA4	0.1	269						
	65	M4	1.2	42.5	M4	1.2	42.5	M4	1.8	39.2
*	66	MB4	0.2	112.3						
	67	2MKS4	0.2	110.7						
	68	SN4	0.3	30.1	SN4	0.2	30.3	SN4	0.1	30.8
	69	3MN4	0.1	306.4						
	70	MS4	1.3	63.4	MS4	1.3	63.4	MS4	1.8	72.5
	71	MK4	0.5	47.7	MK4	0.5	47.6	MK4	0.7	60.9
	72	2MSN4	0	221.4						
	73	S4	0.2	91.9	S4	0.2	91.9	S4	0.3	110.9
	74	SK4	0.2	100.9	SK4	0.2	100.9	SK4	0.1	185.2
	75	2MQ5	0.6	4.8						
	76	2MO5	1.1	23.8						
*	77	MA5	0.1	136.3						
	78	M5	0.4	92						
*	79	MB5	0.1	254.2						
	80	2MS5	0.1	3.3						
	81	3MQ5	0.2	214						
	82	MSK5	0.9	358						
	83	4MK6	0.1	280.3						
	84	4MS6	0.9	259.5						
	85	2MSNK6	0.1	297.8						
	86	2MN6	1.5	133.1	2MN6	1.5	133	2MN6	1.5	139.5
	87	2Mnyu6	0.6	115.7						
	88	3MSK6	0.2	329.3						
	89	MA6	0.1	261						
	90	M6	3.1	143.7	M6	3.1	143.6	M6	3.3	149.6
	91	MB6	0.1	239.9						
	92	MSN6	0.8	176.1	MSN6	0.8	176.5	MSN6	1	184.9
	93	4MSN6	0.5	314.1						
	94	2MS6	4.2	175.8	2MS6	4.2	175.8	2MS6	4.5	183.3
	95	2MK6	1.2	169.3	2MK6	1.2	169.4	2MK6	1.3	178.1
	96	3MSN6	0.9	354						
	97	2SM6	1.2	223.1	2SM6	1.2	223.2	2SM6	0.9	220.2
	98	MSK6	0.8	209.4	MSK6	0.8	209.2	MSK6	0.8	224.4
	99	3MQ7	0.2	44.7						
	100	4MK7	0.3	60.6						
	101	MNSO7	0.2	84.2						
	102	MA7	0	190.5						
	103	M7	0	322.4						
	104	MB7	0	315.8						
	105	3MK7	0.2	83.8						
	106	MSKO7	0.2	311.7						
	107	2(MN)8	0.1	320.4						
	108	3MN8	0.1	302						
	109	MA8	0	93.2						
	110	M8	0.2	358.3						
	111	MB8	0	251.4						

112	2MSN8	0.1	17.6		
113	3MS8	0.4	37.5		
114	4MSN8	0	339.7		
115	2(MS)8	0.2	90.1		
116	3MNO9	0.1	74.8		
117	2(MN)K9	0	79.2		
118	MA9	0	242		
119	M9	0.1	134.9		
120	MB9	0	7.8		
121	4MK9	0.1	118.1		
122	3MSK9	0.2	182.6		
123	3M2N10	0.1	304.2		
124	4MN10	0.1	350.6		
125	MA10	0	94.8		
126	M10	0.1	17.2		
127	MB10	0	92.9		
128	3MSN10	0.3	7.7		
129	4MS10	0.5	23.5		
130	2(MS)N1(	0.1	94.3		
131	3M2S10	0.4	61.7		
132	3SMN10	0	201.6		
133	3S2M10	0.1	112.8		
134	MA11	0	243.9		
135	M11	0	312.1		
136	MB11	0	292		
137	XMS11	0.1	63.9		
138	4MSK11	0	2.5		
139	5MN12	0	138.2		
140	MA12	0	27.1		
141	M12	0	146.5		
142	MB12	0	62.3		
143	4MSN12	0	141.1		
144	5MS12	0.1	88.4		
145	3M2SN12	0	212		
146	4M2S12	0	168		
147	3(MS)12	0	288.5		