CHAPTER 23

Studies on the Correlation of Tidal Elevation Changes Along the Western Coastline of Taiwan

By

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Abstract

In order to understand the characteristics of tidal elevation changes along the western coastaline of Taiwan, the authors collected the tidal records at the same duration from eleven stations and made an elaborate analysis in this paper.

First step, the main tidal constituents were picked out from spectrum analysis, and the amplitudes and phase angles of these tidal constituents would be obtained by harmonic analysis. Then the variations of amplitude and phase lag of the main constituents and the variations of mean high water level and mean low water level along the coastline would be presented in the figures respectively. Finally, based on the results of harmonic analysis, the energy density of tide for every station could be calculated separately, and the location of the maximum energy density would be determined by cubic spline method.

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1. Introduction

Taiwan is a narrow island in the western Pacific Ocean, between the East and South-China sea. It is separated from the mainland of China by Taiwan Strait, about 130Km at the nearest part. Under this particular geographical boundary conditions, every time as the tide flooding, sea water flows into the strait from the southern and northern entrance simultaneously, and the flooding water concentrate gradually at one point of the strait until the maximum water level reaches. Then the tide ebbing, water flows back from the strait along the same route to the Pacific Ocean. Through this particular tidal movements, the amplitude of tide varies along the coastline which is only about 0.64m at the southest of Taiwan, and about 0.90m at the northest. But around Tai-Chiung coastal area which closes to the middle point of the coastline, the tidal range reaches 5.85m approximately. In order to understand the characteristics of tidal elevation changes along the western coastline of Taiwan, the authors collected the tidal records of the same duration of 11 stations from Kee-Lung, Tan-Hsui, Chu-Wei, Yung-An, Tai-Chiung, Fang-Yuan, Tai-Hsi, Wen-Kang, Chiang-Chun, Kao-Hsiung and Hsun-Kuan-Tsui shown in Fig-1.

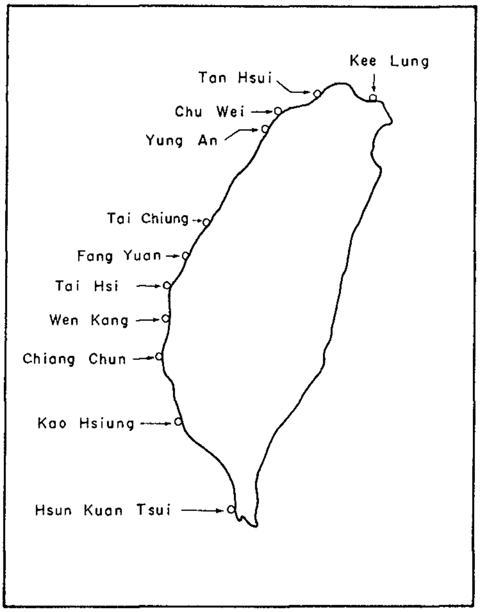

Fig-1

Based on these collected records, the main tidal constituents would be obtained from power spectrum analysis. Then the amplitudes and phase angles of these constituents were also obtained by harmonic analysis. Furthermore, the characteristics of tidal constituents along the western coastaline of Taiwan are presented in this paper.

2. Data Collection and Analysis

In order to inspect the tidal records, firstly, all the collected data for every station would be plotted as a continuous curve shown from Fig-2(a) through Fig-2(k) separately. Since the tidal records may include meteorological tide or storm surge as typhoon passing through around Taiwan island, that the abnormal tide has to be filtered from the records before all of the analysis are made.

Afterwards, the main tidal constituents can be picked out from the spectrum analysis, that 8,192 tidal records ($\Delta f=0.04394^0/hr$) were taken to do the analysis for every station. And the results were presented from Fig-3(a) through Fig-3(k) respectively.

Then based on these main tidal constituents picked out from spectrum analysis, the harmonic constants (amplitudes and phase angles) would be obtained from harmonic analysis by least square method. And after the arguement and correction coefficient of these tidal constituents were determined that the tide function could be established for every station.

3. Results and Discussions

According to the above results of spectrum analysis from Fig-2 (a) through Fig-2(k), it is well to see that the variations of water elevation along the western coast of Taiwan are dominated by semi-diurnal and diurnal tide simultaneously.And it is found that the energy of semi-diurnal tide is the highest at Tan-Hsui, Chu-Wei, Yung-An, Tai-Chiung, Fang-Yuan, Tai-Hsi, Wen-Kang and Chiang-Chun stations. But beyond the above stations, it is said, that Kee-Lung, Kao-Hsiung and Hsun-Kuang-Tsui stations are dominated both by semi-diurnal and diurnal tides.

Then, based on the spectrum analysis, we picked out twenty-five tidal constituents which the summation of energy has occupied over 90% of the tide for every station. Accordingly, the harmonic analysis by least square method was carried out for every station separately. And the results were tabulated in Table-1(a)∿Table-1(k).

In general, the type of tide can be classified from the ratio ,R, between the summation amplitude of diurnal tides (K_1,O_1) and semi-diurnal tides (M_2,S_2). As $R\leqslant 0.25$, the tide is a semi-diurnal type, $0.25\leqslant R\leqslant 1.50$, is a mixed-type and $1.50<R$ that it is a diurnal type. Thus, from the results of harmonic analysis, the ratio,R, could be calculated for every station and listed in Table-2 respectively. And it is obviously to see that the tide between the water area of Tan-Hsui and Tai-Hsi is a semi-diurnal type, but out of this region is a mixed-type.

And the variations of amplitude and phase lag of the main constituents along the latitude of western coast from the south to the north of Taiwan island were presented in Fig-4 and Fig-5 respectively. It is obviously to see that all the amplitude of tidal constituents increas with the latitude increasing, and reach a maximum value around Tai-Chiung station, then the amplitude decreas with the latitude increasing. As for the phase lag, we can see that the tendency of variations of phase lag are the same as amplitude does along the latitude, but the larger the angular frequency of tidal constituent is, the larger the phase lag has. Likewise, the variation of the mean high water level, MHW, and mean low water level, MLW, along the latitude are shown in Fig-6.

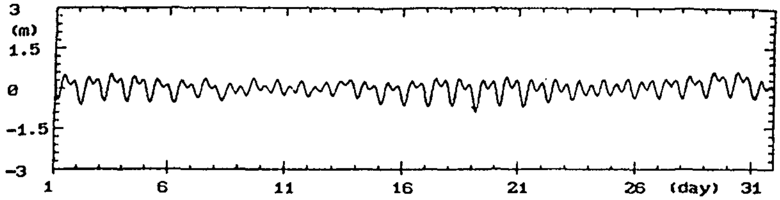

Fig-2(a) Kee-Lung JAN. 1980

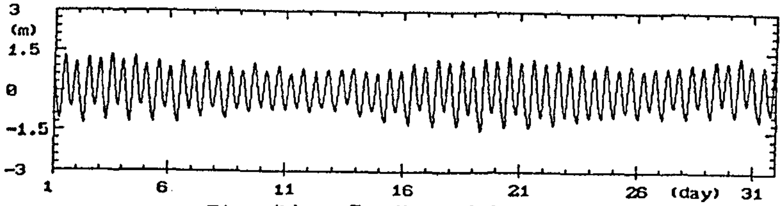

Fig-2(b) Tan-Hsui JAN. 1980

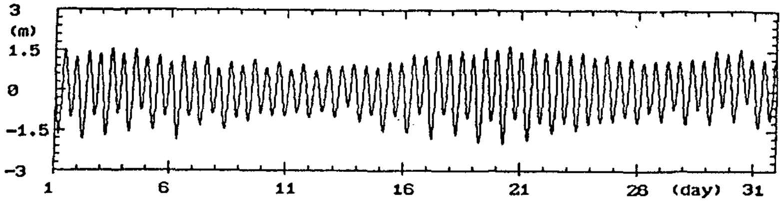

Fig-2(c) Chu-Wei JAN. 1980

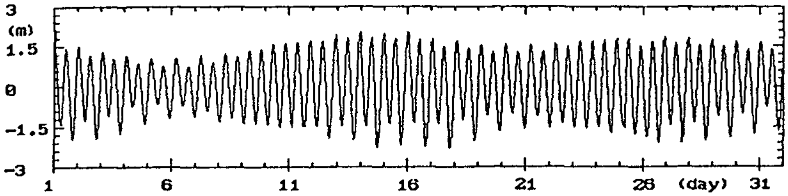

Fig-2(d) Yung-An MAY. 1983

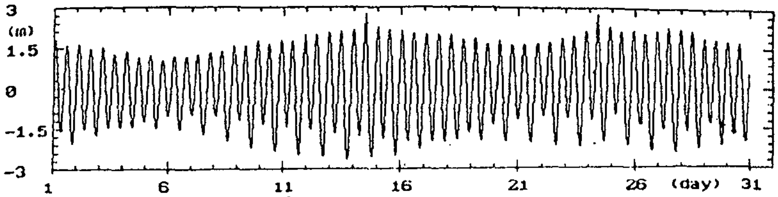

Fig-2(e) Tai-Chiung JUN. 1972

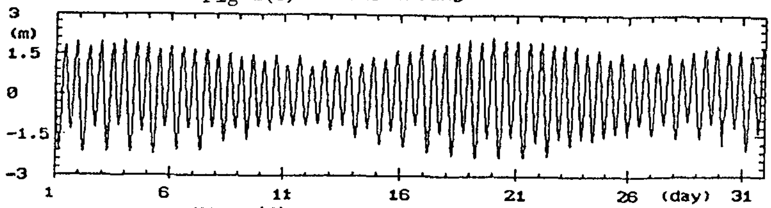

Fig-2(f) Fang-Yuan JAN. 1980

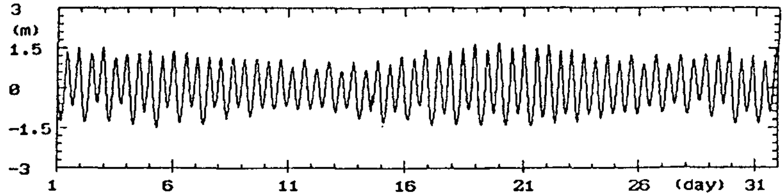

Fig-2(g) Tai-Hsi JAN. 1980

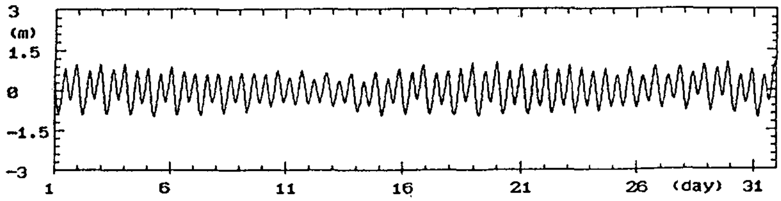

Fig-2(h) Wen-Kang JAN. 1980

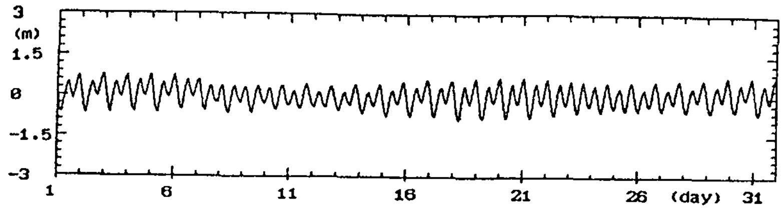

Fig-2(i) Chiang-Chun JAN. 1980

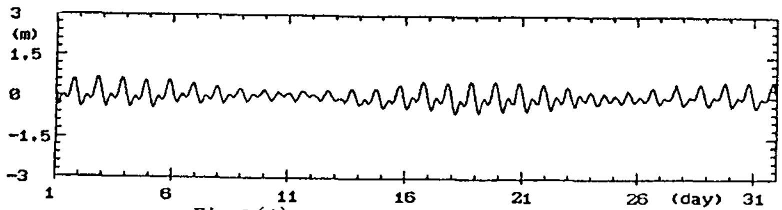

Fig-2(j) Kao-Hsiung JAN. 1980

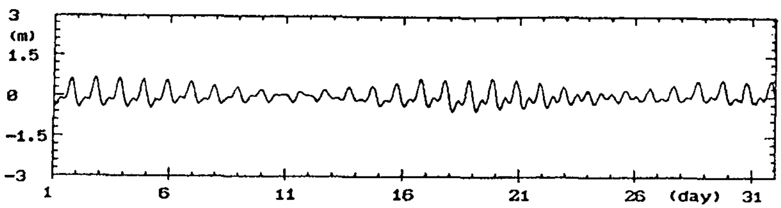

Fig-2(k) Hsun-Kuang-Tsui JAN. 1980

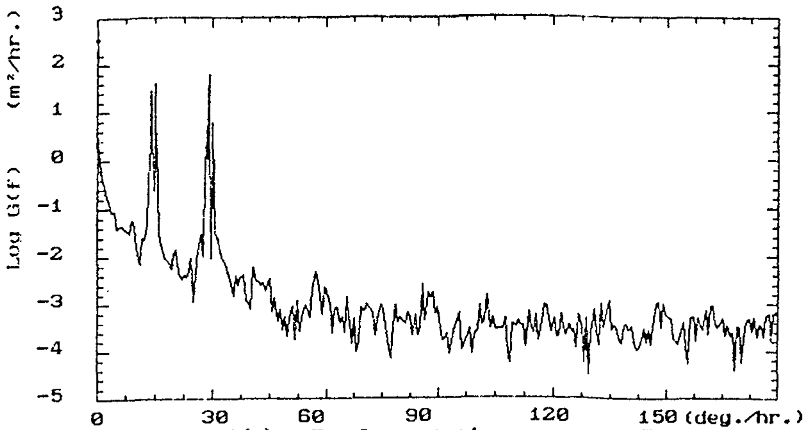

Fig-3(a) Kee-Lung station Freq.

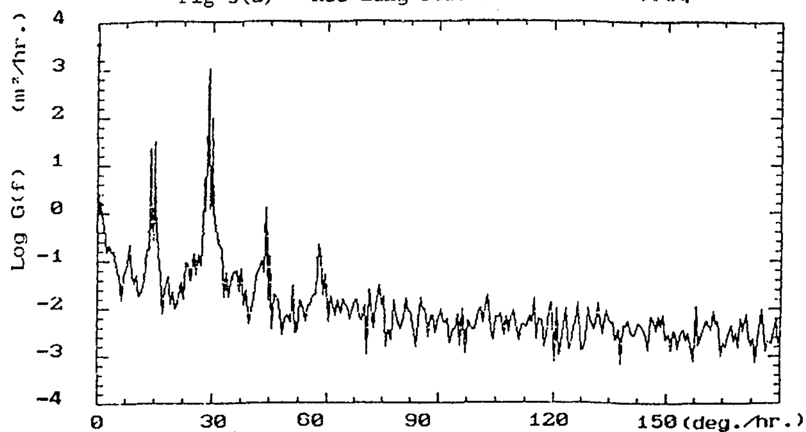

Fig-3(b) Tan-Hsui station Freq.

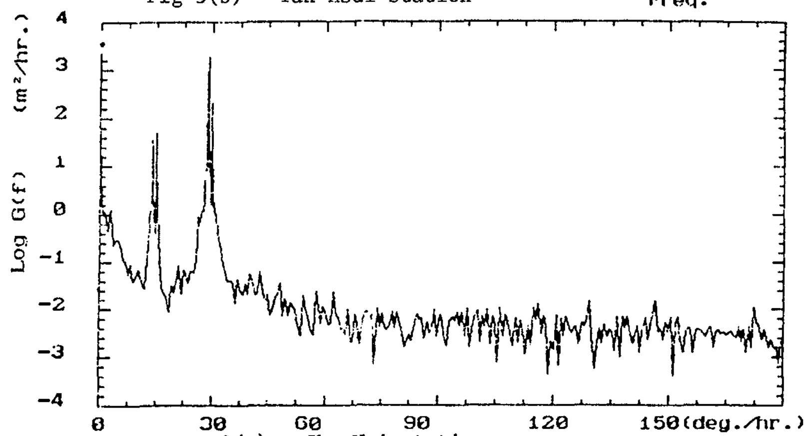

Fig-3(c) Chu-Wei station Freq.

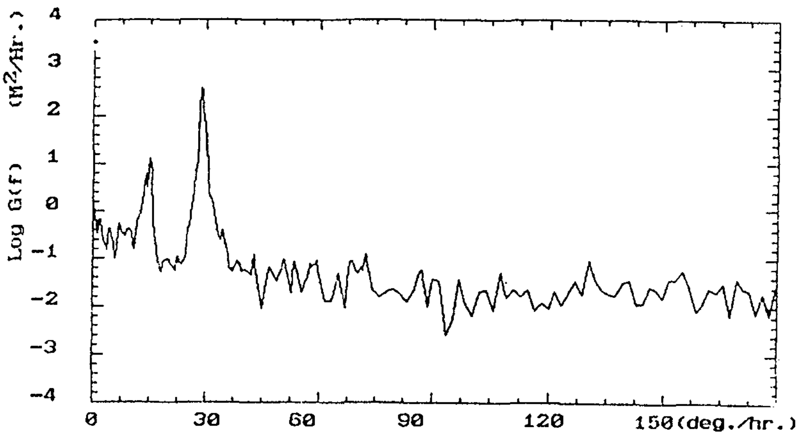

Fig-3(d) Yung-An station

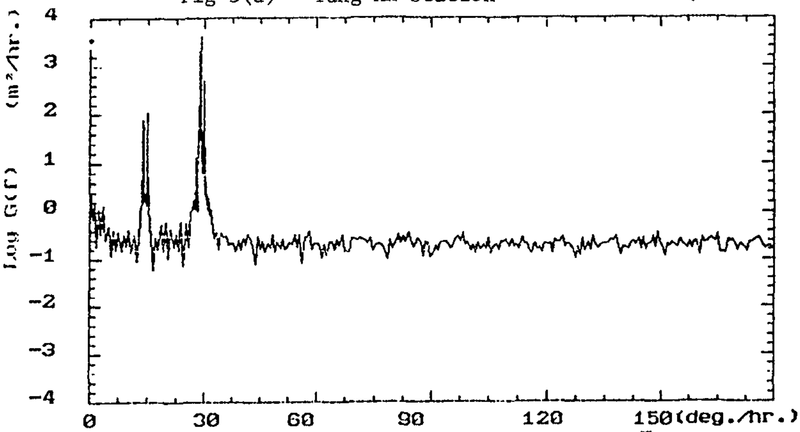

Fig-3(e) Tai-Chiung station

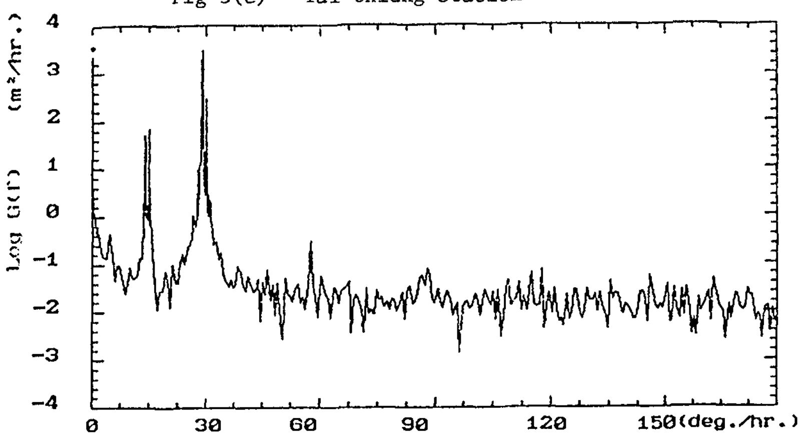

Fig-3(f) Fang-Yuan station

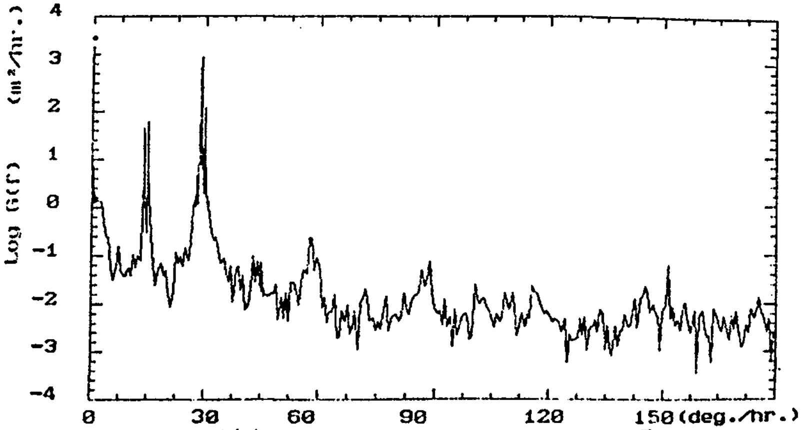

Fig-3(g) Tai-Hsi station

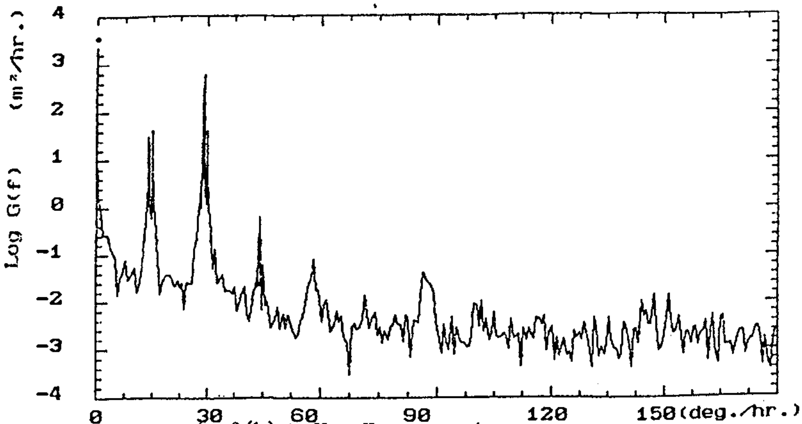

Fig-3(h) Wen-Kang station

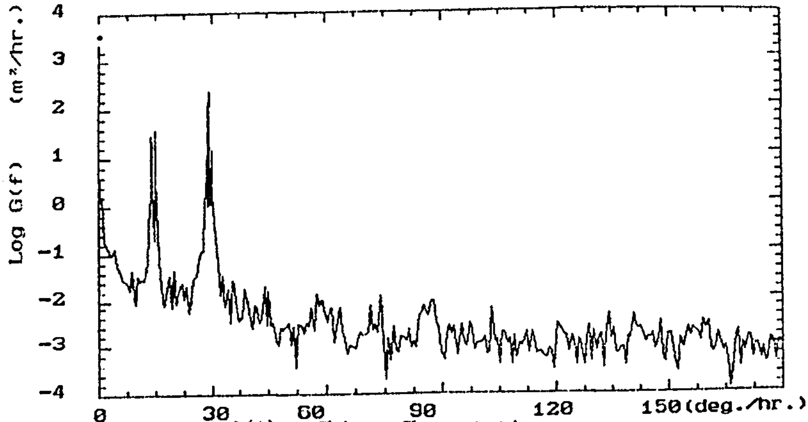

Fig-3(i) Chiang-Chun station

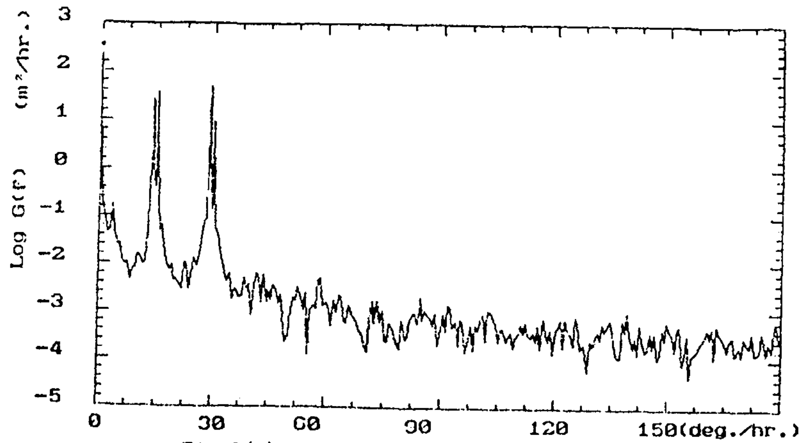

Fig-3(j) Kao-Hsiung station

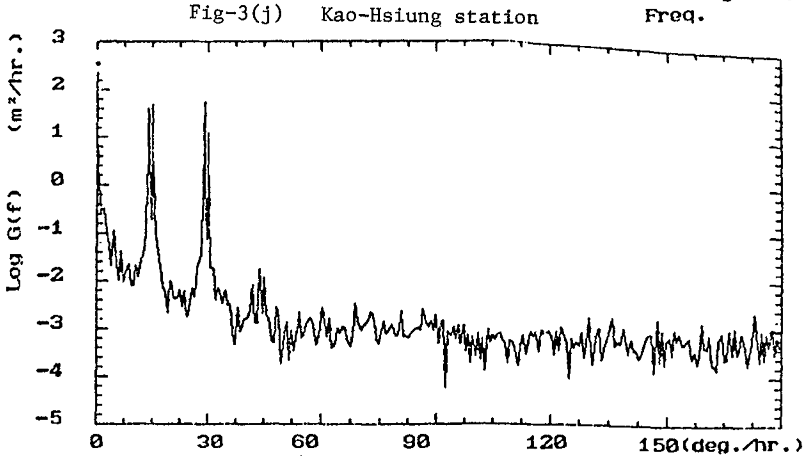

Fig-3(k) Hsun-Kuang-Tsui station

Table-1(a) Table-1(b)

Kee-Lung				Tan-Hsui			
No	Name	ampl	phase	No	Name	ampl	phase
1	M2	.2100	314.7	1	M2	.8401	13.8
2	K1	.1524	228.0	2	S2	.2289	23.6
3	O1	.1510	220.7	3	Sa	.1715	141.1
4	Sa	.1474	132.3	4	N2	.1461	4.0
5	P1	.0614	229.1	5	K1	.1300	257.4
6	S2	.0550	282.4	6	O1	.1355	257.0
7	N2	.0520	302.0	7	K2	.0670	11.0
0	Q1	.0304	223.8	8	P1	.0606	263.5
9	MJU2	.0250	200.4	0	MJU2	.0562	101.4
10	NJU2	.0147	323.5	10	M4	.0555	336.5
11	Mf	.0140	33.0	11	NJU2	.0400	8.0
12	L2	.0145	34.1	12	L2	.0436	23.0
13	K2	.0140	272.1	13	OP2	.0404	355.9
14	M4	.0096	343.3	14	MS4	.0367	349.1
15	2N2	.0085	247.8	15	Ssa	.0352	2.0
16	Mm	.0085	97.9	16	MK3	.0209	249.0
17	J1	.8802	232.0	17	Msf	.0204	357.5
10	MS4	.8877	338.0	18	Q1	.0250	254.4
18	Ssa	.0072	335.8	18	Mf	.8238	13.4
20	LUM8A2	.0070	29.1	20	Mm	.8204	48.6
21	Msf	.0000	294.3	21	MN4	.0202	330.0
22	M3	.0059	215.1	22	MO3	.0195	240.1
23	MNS2	.0050	179.7	23	LUM8A2	.0184	2.6
24	T2	.0050	271.6	24	MNS2	.8143	180.6
25	PSI1	.0047	101.9	25	2N2	.8125	333.8

Table-1(c) Table-1(d)

Chu-Wei				Yung-An			
No	Name	ampl	phase	No	Name	ampl	phase
1	M2	1.1020	351.1	1	M2	1.4170	339.4
2	S2	.3172	357.0	2	S2	.4100	11.2
3	N2	.2157	340.0	3	K1	.3325	230.6
4	U1	.1662	245.2	4	O1	.2004	229.9
5	K1	.1631	246.4	5	N2	.1071	335.6
6	Sa	.1441	137.5	6	M4	.0147	107.3
7	K2	.1009	1.6	7	MS4	.0220	215.1
0	P1	.0630	241.6				
8	OP2	.0570	201.1				
10	L2	.0541	355.7				
11	MJU2	.0510	170.0				
12	MKS2	.0430	55.3				
13	NJU2	.0425	340.3				
14	Ssa	.0417	51.7				
15	T2	.0386	307.2				
16	Q1	.0334	240.3				
17	M4	.0240	209.0				
10	MS4	.0222	209.0				
19	A2	.0207	79.5				
20	Msf	.0101	137.1				
21	LUMDA2	.0136	344.0				
22	MNS2	.0131	161.7				
23	2SM2	.0120	240.0				
24	PSI1	.0116	314.7				
25	Mf	.0113	89.0				

Table-1(e) Table-1(f)

Tai-Chiung				Fang-Yuan			
No	Name	ampl	phase	No	Name	ampl	phase
1	M2	1.7028	5.3	1	M2	1.4776	352.3
2	S2	.5100	4.7	2	S2	.4888	5.3
3	N2	.3259	30.0	3	N2	.2575	343.9
4	K1	.2422	232.2	4	O1	.1969	204.3
5	O1	.1020	299.6	5	K1	.1024	270.7
8	Sa	.1595	05.0	0	Sa	.1537	100.4
7	K2	.1391	290.1	7	K2	.0959	2.8
0	L2	.1098	339.4	0	NJU2	.0070	4.7
8	NJU2	.0919	330.2	9	MJU2	.8764	151.3
10	MJU2	.8798	104.0	10	P1	.0729	278.4
11	P1	.0743	289.5	11	L2	.0684	5.1
12	O1	.0427	334.5	12	M4	.0570	270.1
13	LUMOA2	.0372	51.4	13	LUMOA2	.8545	336.7
14	2N2	.0329	11.0	14	MKS2	.0517	100.7
15	T2	.0201	10.3	15	OP2	.0427	108.4
10	M4	.0205	311.5	16	Q1	.0373	265.0
17	Ssa	.0201	255.6	17	R2	.0371	160.4
10	MNS4	.0232	207.6	18	MS4	.0344	290.1
19	2SM2	.8229	251.5	19	M6	.0251	264.1
20	MSN2	.0220	183.2	20	2MS6	.8241	205.2
21	MN4	.0154	295.2	21	MNS2	.0231	119.0
22	MKS2	.0151	205.0	22	MN4	.0224	272.0
23	MS4	.0147	207.8	23	MK3	.8284	217.0
24	KJ2	.0137	70.4	24	2SM2	.0199	245.7
25	M3	.0123	113.7	25	MSN2	.0185	188.2

Table-1(g) Table-1(h)

Tai-Hsi				Wen-Kang			
No	Name	ampl	phase	No	Name	ampl	phase
1	M2	.8958	354.5	1	M2	.6387	352.5
2	S2	.2402	11.0	2	Sa	.1043	155.3
3	O1	.1087	272.2	3	O1	.1606	200.0
4	N2	.1027	345.1	4	K1	.1575	207.1
5	K1	.1700	201.5	5	S2	.1400	0.0
6	Sa	.1765	140.0	6	N2	.1299	330.4
7	K2	.0094	8.7	7	Ssa	.0670	62.6
8	P1	.0641	209.5	0	L2	.0521	13.9
8	Ssa	.0519	07.4	9	P1	.0499	291.1
10	NJU2	.0509	347.7	10	K2	.0400	10.5
11	M4	.0406	14.4	11	MJU2	.0304	151.0
12	LUMDA2	.0455	353.6	12	Q1	.0370	275.0
13	OP2	.0427	130.2	13	OP2	.0335	202.5
14	Q1	.0390	270.0	14	NJU2	.0291	351.7
15	T2	.0376	311.4	15	MK3	.0219	226.7
10	L2	.0374	344.4	10	MKS2	.0217	112.1
17	MS4	.0310	32.2	17	M4	.0103	349.5
10	MJU2	.0291	129.7	10	Mm	.0174	91.5
18	MKS2	.0239	180.0	19	M6	.0170	303.0
20	M6	.0225	299.1	20	Msf	.0157	209.0
21	MNS2	.0215	77.3	21	2MS6	.0154	331.0
22	2MS6	.0206	321.2	22	PAI1	.0147	270.7
23	Mf	.0206	13.5	23	MNS2	.0146	141.6
24	MN4	.0205	357.9	24	2N2	.0130	296.6
25	Mm	.0204	350.0	25	OQ2	.0134	239.3

Table-1(i)

Chieng-Chun			
No	Name	ampl	phase
1	M2	.4241	352.6
2	O1	.1496	283.4
3	K1	.1455	290.7
4	Sa	.1450	150.8
5	S2	.0927	4.2
0	M2	.0733	344.2
7	P1	.0573	291.2
R	Q1	.0205	284.7
8	MJU2	.0269	173.2
10	MJU2	.0212	324.2
11	L2	.0176	11.3
12	K2	.0156	13.6
13	Mm	.0153	73.4
14	MKS2	.0149	157.4
15	OP2	.0147	167.7
16	MK3	.0128	227.0
17	LUMDA2	.0118	59.8
10	R2	.0117	139.7
18	MNS2	.0100	141.0
20	MS4	.0097	34.4
21	M4	.0096	.3
22	Ssa	.0093	263.6
23	J1	.0081	310.0
24	M6	.0080	332.9
25	MO3	.0079	220.0

Table-1(j)

Kao-Hsiung			
No	Name	ampl	phase
1	M2	.1828	253.6
2	O1	.1525	273.1
3	K1	.1421	284.0
4	Sa	.1200	156.1
5	S2	.0672	230.0
6	Ssa	.0580	55.7
7	P1	.0561	284.1
8	N2	.0384	258.2
9	Q1	.0320	268.3
10	K2	.0100	255.4
11	Mf	.0152	68.6
12	MJU2	.0105	214.0
13	Msf	.0080	296.5
14	2N2	.0084	269.6
15	T2	.0082	107.0
16	J1	.0073	279.7
17	OO1	.0069	75.0
18	OP2	.0066	123.0
19	NJU2	.0064	271.5
20	PSI1	.0062	75.3
21	Mm	.0061	79.3
22	SO1	.0055	100.2
23	SIGMA1	.0040	209.0
24	RHO1	.0046	273.1
25	MKS2	.0044	243.1

Table-1(k)

Hsun-Kuan-Tsui			
No	Name	ampl	phase
1	M2	.1875	235.6
2	O1	.1729	270.4
3	K1	.1629	282.0
4	Sa	.1320	150.7
5	S2	.0801	229.1
6	Ssa	.0846	69.9
7	P1	.0606	278.0
8	M2	.0355	251.0
9	Q1	.0323	277.7
10	K2	.0181	252.7
11	Mf	.0151	33.8
12	T2	.0128	253.3
13	MKS2	.0107	345.2
14	S1	.0098	59.0
15	OP2	.0095	141.0
16	PSI1	.0090	270.6
17	R2	.0080	195.3
18	Msf	.0085	301.2
19	J1	.0083	280.7
20	MJU2	.0070	244.7
21	THITA1	.0060	93.7
22	2N2	.0066	294.3
23	RHO1	.0057	263.9
24	L2	.0055	192.5
25	MP1	.0055	248.3

Table — 2

Station	R	Station	R
Kee — Lung	1.139	Tai — Hsi	0.297
Tan — Hsui	0.253	Wen — Kang	0.403
Chu — Wei	0.231	Chiang — Chun	0.571
Tai — Chiung	0.189	Kao — Hsiung	1.179
Fang — Yuan	0.206	Hsun — Kuan-Tsui	1.255

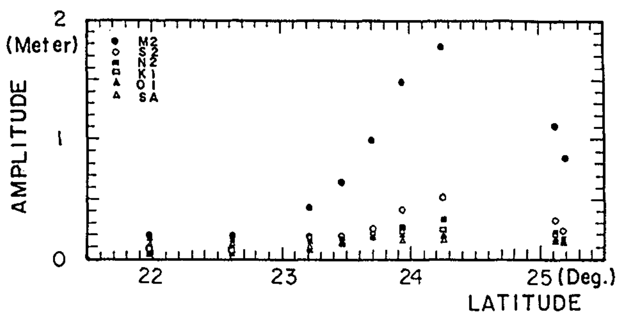

Fig-4 The relationships between the amplitude and latitude

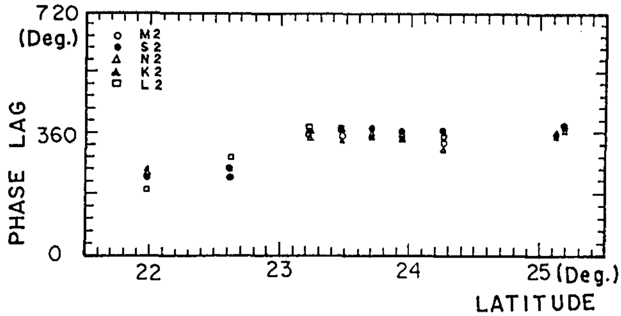

Fig-5 The relationships between phase lag of semi-diurnal and latitude

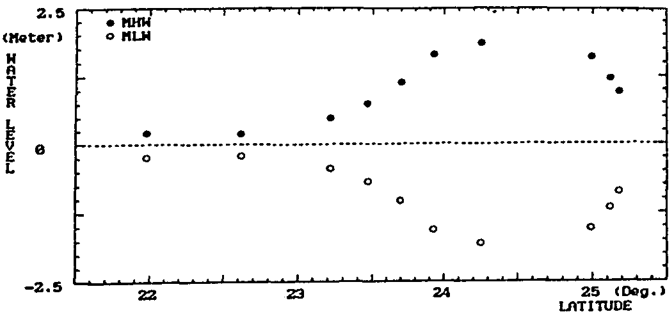

Fig-6 Variation of MHW and MLW

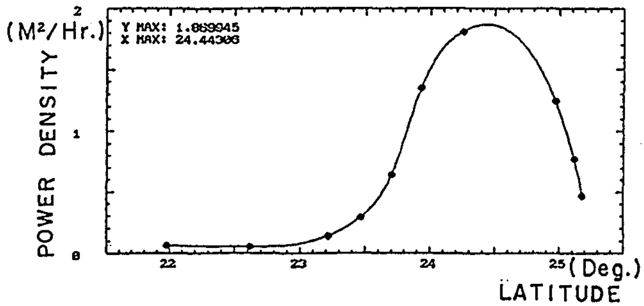

Fig-7 The distribation of energy density along the western coast of Taiwan

the location is 24° 26′, it is said that 20.9km north of Tai—Chiung station

Finally, based on the main tidal constituents obtained from harmonic analysis, the energy density of tide for every station could be calculated and the result was shown in Fig-7. Then the maximum energy density could be determined by cubic spline method, that is to say, the maximum tidal range is located 20.9Km north of Tai-Chiung station.

4. Conclusions

According to the above results, some of the remarkable conclusions would be made in this paper. They are:

(1). Along the western coast of Taiwan island, twenty-five tidal constituents picked out from the spectrum analysis are enough for engineering uses, because of the summation of energy density of these tidal constituents has occupied over 90% of the tide.

(2). The tide between Tan-Hsui and Tai-Hsi station is a semi-diurnal type which is especially dominated by M_2 constituent. However, out of this region, the tide is a mixed type which is dominated by diurnal and semi-diurnal tides simultaneously.

(3). Although the tidal records of eleven stations along the western coast of Taiwan were collected as possible as in this paper. Accordingly, the location of the maximum tidal range is determined about 20.9Km north from Tai-Chiung station. However, the more tidal stations will be provided for analysis, the more accuracy will be obtained.

5. References

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