STUDY ON THE TEMPORAL VARIATION OF TIDAL CHARACTER BY GLOBAL WARMING IN THE WEST SEA OF KOREA

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***Abstract:** the rise of sea levels and the variety of tidal characteristics by its increasing as a result of global warming is one of the important problems in oceanography research.*
In this paper, we have proposed a statistical analysis model for tide character variation analysis and analyzed tidal characteristic temporal variation in the researching area (West Sea Korea).
As a result of research, it is believed that tide-level has risen in the past century in the researching area and the model we proposed in this paper is available for tide character temporal variation analysis.

***Keywords:** global warming, tidal character variation, non-harmonic constant, regressive analysis.*

ИССЛЕДОВАНИЕ ОБ ИЗМЕНЧИВОСТИ ХАРАКТЕРИСТИКИ ПРИЛИВА ПРИ ГЛОБАЛЬНОМ ПОТЕПЛЕНИИ В КОРЕЙСКОМ ЗАПАДНОМ МОРЕ

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***Аннотация:** повышение уровня моря и изменение характеристики прилива из-за его повышения в результате глобального потепления являются одной из важных проблем в исследовании океанологии.*
В статье предложили статистическую аналитическую модель для объяснения изменчивости характеристики прилива в изучаемой акватории и раскрыли её временную изменчивость.
В резулитате исследования уточнили повышение уровня прилива за прошлый век в изучаемой акватории и утверждали то, что предлагаемая модель полезна для объяснения временной изменчивости характеристики прилива.

***Ключевые слова:** глобальное потепление, изменение характеристики прилива, негармоническая константа, регрессионный анализ.*

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) issued the First Assessment Report (FAR) in 1990, the Second Assessment Report (SAR) in 1996, the Third Assessment Report (TAR) in 2001 and most recently the Fourth Assessment Report (AR4), released in 2007 [9, 10].

Global temperatures have risen during the 20th century, especially over the past fifty years [5~7].

In the estimation Fifth Assessment Report(AR5) that IPCC suggests recently, they revaluated that in the last times global temperature rises 0.74 per 100 years, which is different from the Third Assessment Report(TAR) that IPCC suggested in 2001.

Responding to this global temperature of surface seawater rose 0.5 during the same period and it has been more and more increased in recent years.

In the other hand, responding to increasing air temperature and sea water temperature due to global warming, seawater expands, land glacier melts, seawater level rises, and normal ocean conditions change rap idly by the change of ocean current circulation system.

Last century seawater level had got risen 17cmaveragely and its change speed reaches to 0.245cm per year.

About since 1975, while seawater level has risen rapidly, the occupation of glacier in the North Hemisphere has decreased remarkably, which has decreased about 8% during last 30 years.

Climate change, especially global warming will lead to sea-level rise [4, 8].

The global average sea-level will be 0.2 ~ 0.5m higher in 2100 than in 2000.

Sea level is rising by 1 - 2mm/a globally and will have a large impact on the coastal zone. But, the amount of sea level rise differs from region to region [3].

Many coastal areas will experience increased damage from rising sea-levels, floods and storms surges [9, 10].

Also, tide character is one of them.

Trends of annual sea level records of Hugli estuary are studied as -3.82, +0.89, +2.43, +4.85 mm/a respectively [2].

Study area, the West Sea of Korea (Yellow Sea) is tide-coast like this estuary, India.

In this paper, by using a statistical analysis model, non-harmonic constant analysis, we have estimated tide-level variation in the study coast.

2. Material

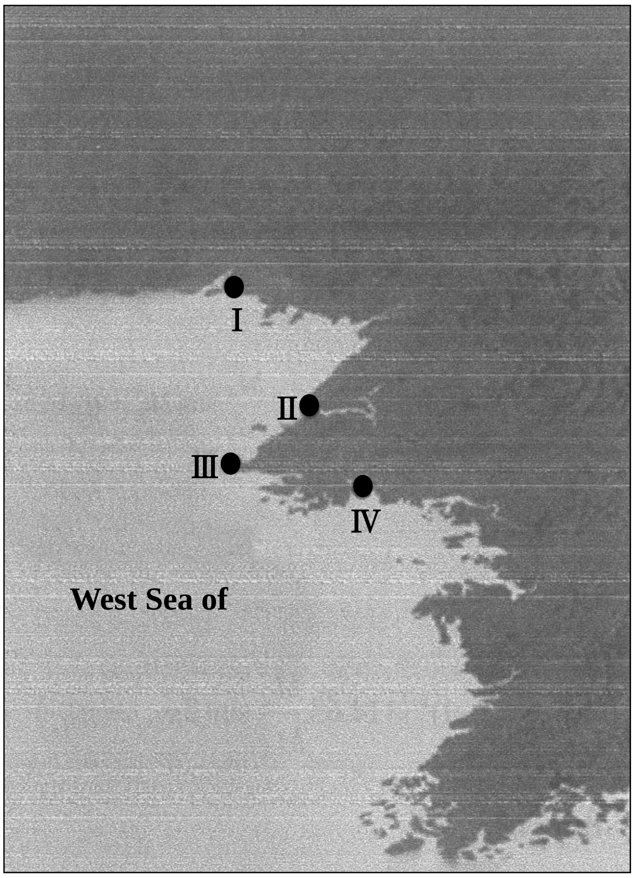

Fig.1. Situation of tide gauges

Data used in this paper is spatial-temporal data of month averaged tide-level in the West Sea of Korea (so called Yellow Sea) (4 spots).

Observation data character by tide gauge shows in table 1.

Table1. Character of Observation Data

Station Num.	Period(year)	Length(year)
Ⅰ	1983 ~ 2013	31
Ⅱ	1985 ~ 2013	29
Ⅲ	1983 ~ 2013	31
Ⅳ	1983 ~ 2013	31

We have got tidal harmonic constants every year monthly by using LSM (Least Square Method) and used as initial data.

3. Theory/calculation

3.1 Non-harmonic constant calculation

The tidal character of tidal coast can be predicted by using non-harmonic constant calculation method on tidal constant.

$$\Delta u_n = 57.3^\circ \cdot \left[\frac{\sin u_n^* + (-1)^n \, 2\frac{M_4}{M_2}\sin\left(2u_n^* + \eta_4\right) + 3\frac{M_4}{M_2}\sin\left(3u_n^* + \eta_6\right)}{\cos u_n^* + (-1)^n \, 2\frac{M_4}{M_2}\cos\left(2u_n^* + \eta_4\right) + 9\frac{M_4}{M_2}\cos\left(3u_n^* + \eta_6\right)} \right] \qquad (1)$$

where,

$$u_n^* = (-1)^{n+1} 114.6^\circ \frac{M_4}{M_2}\sin\left(2g_{M_2} - g_{M_4}\right)$$

$n=0$, it means full, $n=1$ fall.

And

$$\left.\begin{aligned} \eta_4 &= 2g_{M_2} - g_{M_4} \\ \eta_6 &= 3g_{M_2} - g_{M_6} \\ u_0 &= u_0^* - \Delta u_0 \\ u_1 &= u_1^* - \Delta u_1 \end{aligned}\right\}$$

Shallow correction angle on tidal amplitude calculate by

$$\Delta A_0 = M_2\left[\cos\frac{1}{2}(u_0 - u_1) - 1\right] - 0.017M_4(u_0 - u_1)\sin\eta_4 + M_6\cos\frac{3}{2}(u_0 - u_1)\cos\eta_6 \qquad (2)$$

Shallow correction angle on mean range by

$$\Delta L_0 = \frac{1}{2}M_2\left[\cos u_0 - \cos u_1\right] + M_4\cos(u_0 - u_1)\cos\eta_4 - M_6\sin\frac{3}{2}(u_0 - u_1)\sin\eta_6 \qquad (3)$$

Tidal height calculate by

$$h = \Delta L_0 + (A + \Delta A_0)\cos(\sigma_2 t - g_2 - u_n) + B\cos(\sigma_1 t - g_1) \qquad (4)$$

According to the model above, we can calculate variation record of non-harmonic constants equivalent to years.

3.2. Temporal variation calculation of non-harmonic constant

Temporal variation of non-harmonic constant will be able to calculate by using statistical model such as regressive analysis (including linear regressive curve estimation).

We have got tidal harmonic constants every year monthly from tidal observation data by using LS (Least Square Method) and used as initial data. And then have obtained tidal character value time series (i.e. non-harmonic constants time series) by using the tidal harmonic constants, finally calculated trend of its time series through the regressive analysis (including linear regressive curve estimation).

The regressive trend curve means long-term variation of tidal character by Global warming in study area.

4. Results

In our research, after getting tidal character value by using tidal harmonic constant, which constitutes a series of tidal characters (Table 2, 3), we got every time variable tendency of the series, and finally explained long-term tidal character variable of the West Sea of Korea under global warming.

Table 2. Acronym and Mean of Tidal Characters

No.	Acronym	Mean
1	MHHW	Mean Higher High Water
2	MLHW	Mean Lower High Water
3	MHW	Mean High Water
4	MHLW	Mean Higher Low Water
5	MLLW	Mean Lower Low Water

6	MLW	Mean Low Water
7	MHWS	Mean High Water Spring
8	MHWN	Mean High Water Neap
9	MLWS	Mean Low Water Spring
10	MLWN	Mean Low Water Neap
11	MG	MHHW(1)-MLLW(1)
12	MHLLW	MHLW(1)-MLLW(1)
13	MHHW4	Mean Tropical Higher High Water :MHHW(4)
14	MLHW4	Mean Tropical Lower High Water :MLHW(4)
15	MHLW4	Mean Tropical Higher Low Water :MHLW(4)
16	MLLW4	Mean Tropical Lower Low Water :MLLW(4)
17	MHLHW	Mean Tropical High Range :MHHW(4)-MLHW(4)
18	MHLLW	Mean Tropical Low Range : MHLW-MLLW
19	MMHWLW	Mean Half Tidal Surface :(MMHW1-MMLW1)
20	MN1	Mean Tidal Range
21	MN2	Mean Spring Tidal Range
22	MN3	Mean Neap Tidal Range
23	MG2	Mean Spring Maximum Tidal Range
24	MG3	Mean Spring Minimum Tidal Range
25	HHWI	Higher High Water Interval
26	LWI	Low Water Interval
27	HLWI	Higher Low Water Interval
28	LLWI	Lower Low Water Interval
29	LHWI	Lower High Water Interval
30	HWI	High Water Interval
31	MG4	Tropical Higher Range
32	MS4	Tropical Lower Range
33	MN5	Mean Perigee Tidal Range
34	MN6	Mean Apogee Tidal Range
35	MN56	Mean of Perigee and Apogee Tidal Range : (MN5+MN6)/2

Table 3. Calculation Result (at Station Number Ⅰ, on January, 1983)

No.	**Element**	**Value**	**No.**	**Element**	**Value**
1	MHHW	779	19	MMHWLW	511
2	MLHW	732	20	MN1	489
3	MHW	756	21	MN2	659
4	MHLW	296	22	MN3	279
5	MLLW	237	23	MG2	711
6	MLW	267	24	MG3	224
7	MHWS	841	25	HHWI	17.6
8	MHWN	651	26	LWI	5.00
9	MLWS	182	27	HLWI	24.00
10	MLWN	372	28	LLWI	11.60
11	MG	542	29	LHWI	12.30
12	MHLLW	59	30	HWI	17.00
13	MHHW4	755	31	MG4	492
14	MLHW4	707	32	MS4	386
15	MHLW4	322	33	MN5	575
16	MLLW4	262	34	MN6	398
17	MHLHW	47	35	MN56	487
18	MHLLW	59			

Calculation is carried out with MATLAB 2012a and calculation values are shown in Table 4.

Table 4. Variation trend of tidal characters (cm/a)

No.	Elements \ Position Num.	Ⅰ	Ⅱ	Ⅲ	Ⅳ
1	Mean Tidal Range	-0.30	+0.39	-0.01	-0.09
2	Mean Low Water	+0.36	-0.34	+0.03	+0.27
3	Mean Half Water	-0.85	+0.63	+0.07	+0.22
4	Mean Half Tidal Surface	+0.03	+0.03	+0.01	+0.02
…	…	…	…	…	…
35	Low Water Interval(hour/a)	-0.02	-0.01	-0.02	-0.02

As shown in this table, at most of stations high water level is rising (this is related to ascending of sea water level) and lower low water interval (time) is being late.

The other tidal character factors are appearing differently according to character stations.

In figure 2 and 3, temporal change graph of mean range at station Ⅱ, Ⅰ is shown respectively, the range increases more according to the time passing.

The change of tidal character solved in our research should help the institutes that study of tide land, navigation and develop the power resources by using tide in the future, and those who consider the change of ocean factors.

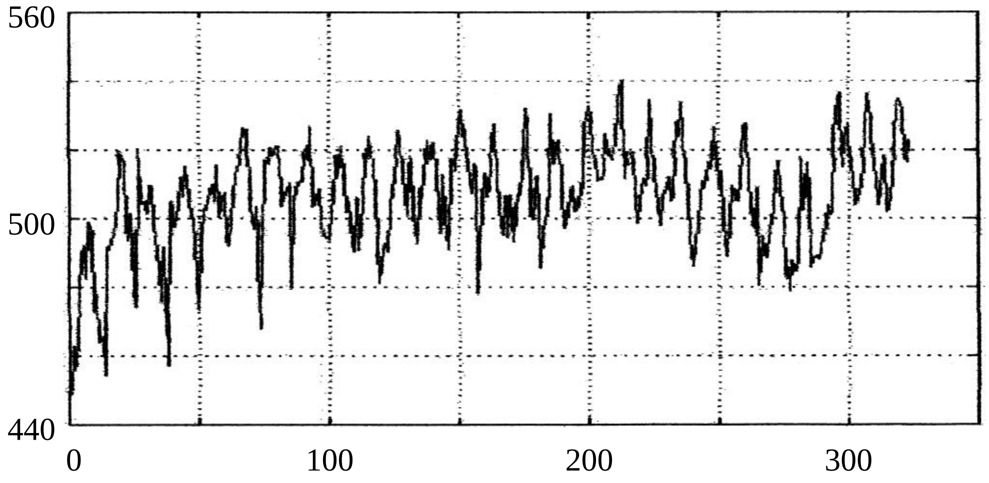

Fig. 2. Graph of mean tidal range character by time (station Ⅱ)

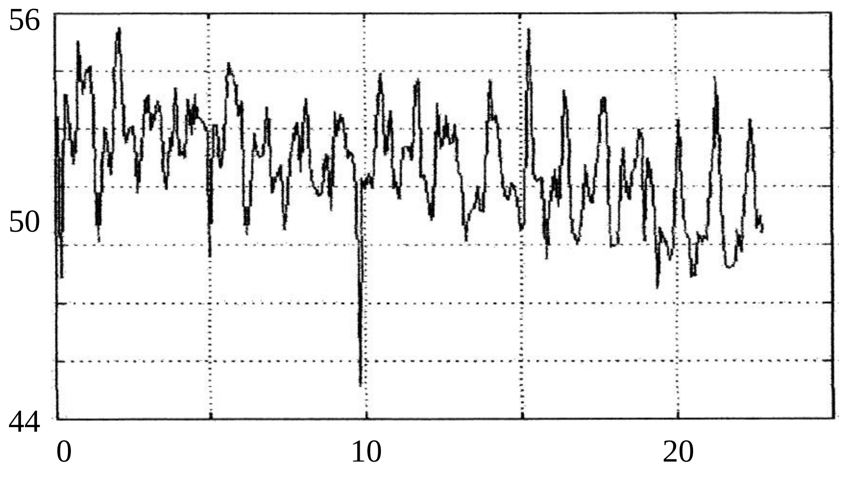

Fig. 3. Graph of mean tidal range character by time (station Ⅰ)

5. Conclusion

IPCC concludes that global mean sea-level rose at an average rate of about 1.7±0.5mm/year during the twentieth century and that the rate has been slightly higher over the period 1961 to 2003.

In this paper, we have proposed a statistical analysis model for tide character variation analysis and analyzed tide character temporal variation in the study area.

As a result of study, we have confirmed as follows.

Firstly, it is convenient to use the non-harmonic constant calculating model and long term changeable extrapolation model of this paper, which considers the effect of littoral tidal component, for the research of tidal character influenced by global warming.

Secondly, the tidal character of sea water we studied is varying remarkably and it will take a great influence to establish the coastal synthesis management plan, such as the tidal power resource development, therefore it must be considered seriously.

We think that this is due to sea level rise, because sea level is one of important factors determining tidal character, especially, sea level obviously have got rising in the study area.

So, we suggest that in theory and practice study on marine science such as Integrated Coastal Management and the tidal power resource development, especially the planning, construction and reinforcement of sea dyke in future, these results must be necessary considered.

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