SEA LEVEL VARIATIONS IN THE LONG TERM IN THE EAST SEA OF KOREA

Keun-Han Cho [1*], Hee-Jong Kim[2], Dong-In Lee[3], Hong-Joo Yoon[1†]

[1]Department of Satellite Information Sciences, Pukyong National University, Korea

[2] Brain Korea 21 Graduate School of Earth Environmental System, Pukyong National University

[3] Department of Environmental Atmospheric Science, Pukyong National University, Korea

599-1 Daeyeon 3-Dong, Nam-Gu, Busan, South Korea

Tel: (82)-51-620-6273 Fax: (82)-51-625-2529

E-mail: yoonhj@pknu.ac.kr

ABSTRACT : Satellite altimetric data from 1993 to 2006 are used to study sea level variations in the long term in the East Sea. The trend of sea level in the East Sea is rising 4.16 ㎜/yr and indicate that it rose 5.82 ㎝ in 2006 against to 1993. The South Ses is the fastest in the study areas (4.89 ㎜/yr, 6.84cm) and the Yellow Sea is 4.10 ㎜/yr and 5.75cm, respectively. The both of Mokho coast and Ulleung island are minimal sea level in March to May and maximal sea level in September to November. For periods above 20.9days, coherences are found to be higher than 95% confidence level, and the phase differences are near zero.

KEY WORDS : Sea level, Altimeter data, East Sea, Filtering, PSD

1. INTRODUCTION

Satellite altimeter data have contributed to very well understand various oceanic phenomena in the world ocean. The East Korean Warm Current (EKWC) flows northward and meets the North Korea Cold Current at 38~39°N near Korean coasts. Meandering of EKWC and a large warm water mass near Ulleung island are permanent features off the east coast. The interior of the meander crest forms the Ulleung Warm Eddy (UWE) (Ichiye and Takano, 1988; Kang and Kang, 1990; Kim *et al.*, 1991). This warm water is referred to as the Ulleung warm lens (Cho *et al.*, 1990). The large variance of monthly mean sea level at Ulleung island might be associated with the path variability of EKWC (YI, 1967). The objective of this work is to investigate the long-term sea level variation the Korean peninsular, especially in the East Sea.

2. DATA

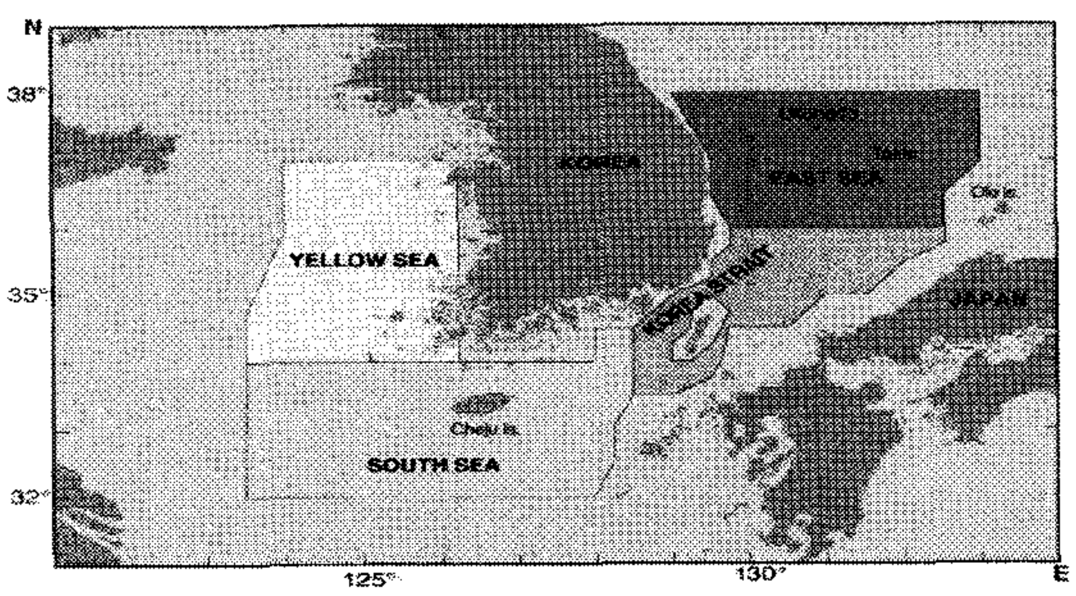

Fig. 1. Oceanographic atlas of the Korean waters (KORDI).

We used gridded delayed time products (DT-MSLA : Delayed Time Map of Sea Level Anomaly) for estimating the characteristic of sea level at the Korean coasts. In delayed time, it is to maintain a consistent and user-friendly altimeter database by SSALTO/DUACS system using the state-of-the-art recommendations from the altimetry community. The Korean peninsular is surrounded by the East Sea, the Yellow Sea and the South Sea, and they have the very different environmental characterisrics. In this study, we studied sea level variations about each sea, especially the East

Sea, after dividing four area near Korean coasts based on Oceanographic Atlas of Korean Waters of Korea Ocean Research & Development Institute (KORDI) (Fig. 1).

3. RESULTS

3.1 Comparison among the East Sea, the South Sea and the Yellow Sea

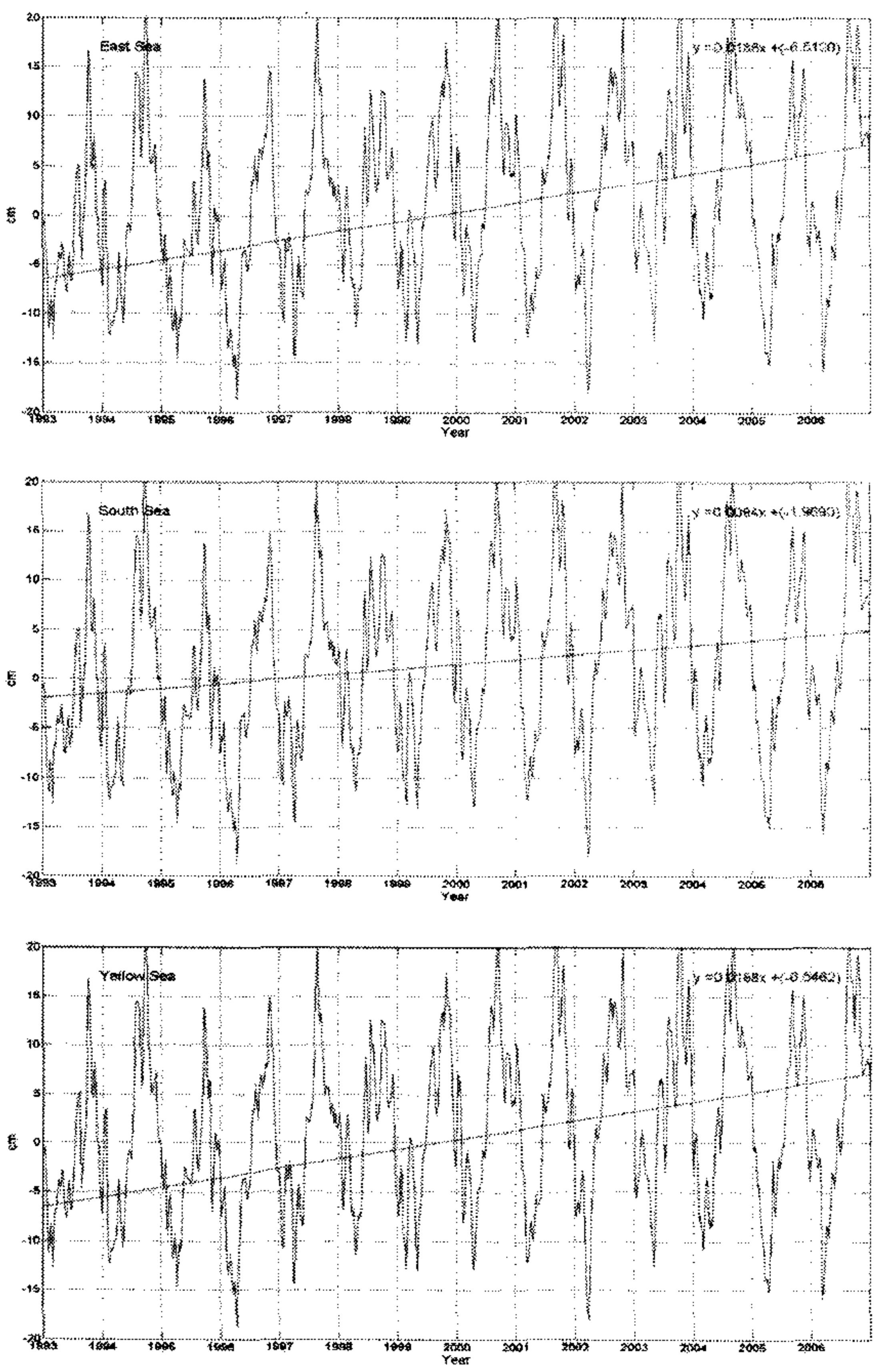

Fig. 2. Sea level variation in the long term and the trend of sea level in the East Sea(top), the South Sea (middle) and the Yellow Sea (bottom).

We averaged spatially altimeter data to estimate sea level variations in the long term and the trend of the sea level among the East Sea, the South Sea and the Yellow Sea from 1993 to 2006(Fig. 2). The trend of sea level in the East Sea is rising 4.16 ㎜/yr and indicate that it rose 5.82 ㎝ in 2006 against to 1993. The South Ses is the fastest in the study areas (4.89 ㎜/yr, 6.84cm) and the Yellow Sea is 4.10 ㎜/yr and 5.75cm, respectively.

The annual peaks presented in the East Sea, the Yellow Sea and the South Sea(Fig. 2). However the energy value of South Sea is the highest against to East and Yellow Sea, and secondly high energy value is the East Sea. Because the South and East Sea are generally dominated by the Kuroshio and Tsushima Current, the energy value is higher than Yellow Sea.

PSD in the East Sea has two unusual peaks which don't present in the Yellow and the South Sea(Fig. 3). That is 245days(0.00408cpd) and 180days(0.0055cpd) peak. Since the peaks of 250days and 180days presented at Mukho and Ulleung island, this peaks will be associated with EKWC, NKCC or eddy activities. Most of peaks of below 125day(0.0079cpd) showed the highest energy value in the Yellow Sea.

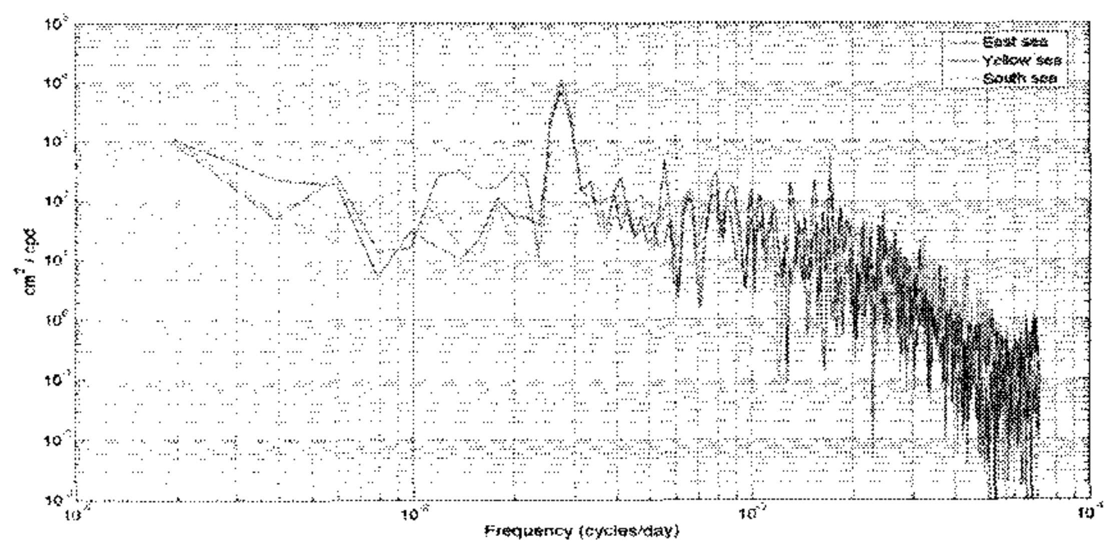

Fig. 3. PSD of sea level in the East Sea, the Yellow Sea and South Sea.

3.2 Monthly mean sea levels at Mukho coast and Ulleung island.

The monthly mean sea levels are shown in Fig. 3. The both of Mokho coast and Ulleung island are minimal sea level in March to May and maximal sea level in September to November. Sea level at Mukho coast is higher than Ulleung island during March to May, while Mukho coast is lower during September to November because influence of the North Korea Cold Current which flows along the coast line near Mukho. Therefore, annual amplitude is low during spring season. On the other hand, Ulleung island is influenced on seasonal variation because it is located on the open sea. Thus, sea level between September and November is high and is low from March to May. Especially, sea level at Ulleung island shows minimal value at the early of spring due to strong cooling effects during winter season. As a result, sea level variation of the east coast near Mukho is dominant by the influence of the North Korea Cold Current and those of Ulleung island is usually decided by the charecteristis of seasonal variation.

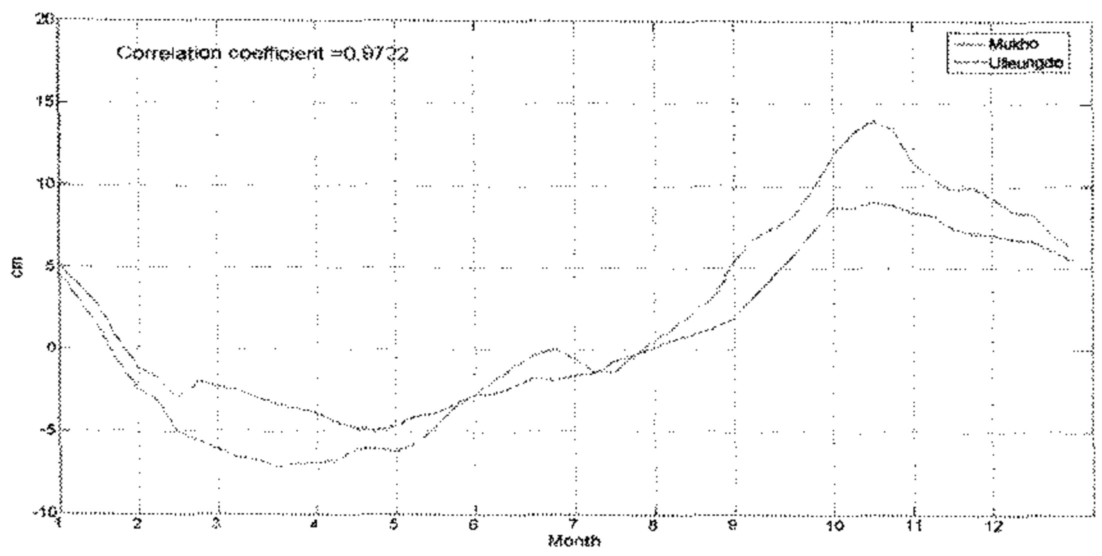

Fig. 4. Monthly mean sea levels at Mukho coast and Ulleung island.

3.3 Sea level variations in the long-term

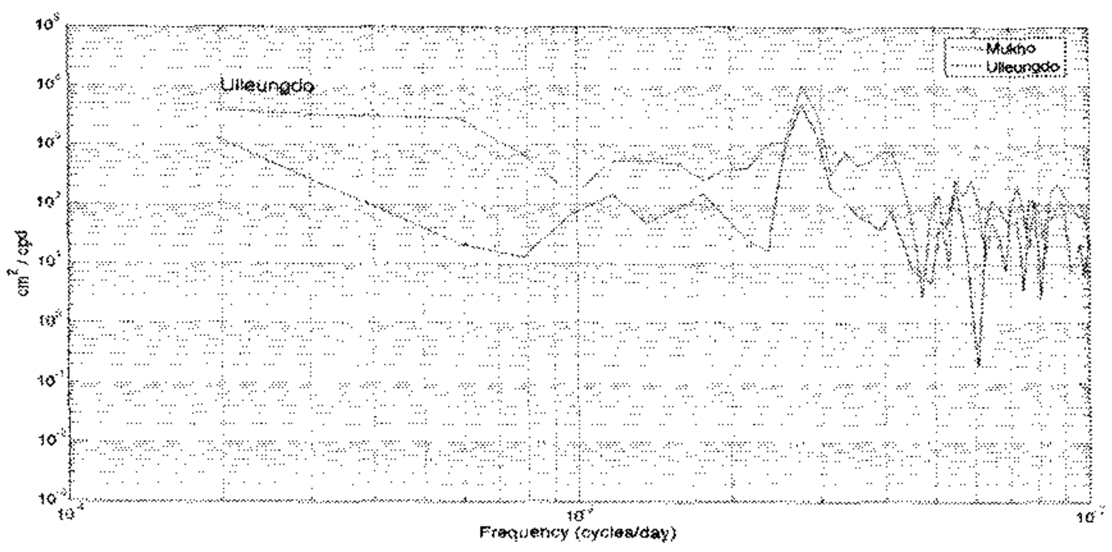

Fig. 5. PSD of sea level at Mukho and Ulleung island.

In order to find more quantitatively the periodicity and the dispersion based on frequency, sea level anomaly data derived from satellite altimeter data were carried out through the PSD.

Fig. 5. shows the PSD of sea level at Mukho coast and Ulleung island. The first significant peak strongly prevails the annual variation both of stations by about 371day(0.0027 cpd). It is well seen that oscillations seasonal sea level are dominated in this spectral analysis. Most of energy value is higher in Ulleung island than Mukho coast, but only energy value of Mukho coast is higher than Ulleung island when the frequency is 0.0065cpd(about 155day). One of the plausible explanation may be influenced by EKWC or NKCC, because Ulleung island is less effected by EKWC or NKCC than Mukho coast. One of the other reason is that Mukho is located on the near coast. Moreoer, the lifetime of the warm and cold eddies may be about 3~5months(about 90~150day)(Akihiko *et. al*, 2000). Thus, this frequency at Mukho coast will be corresponded to the eddy activities with lifetimes of 3~5months.

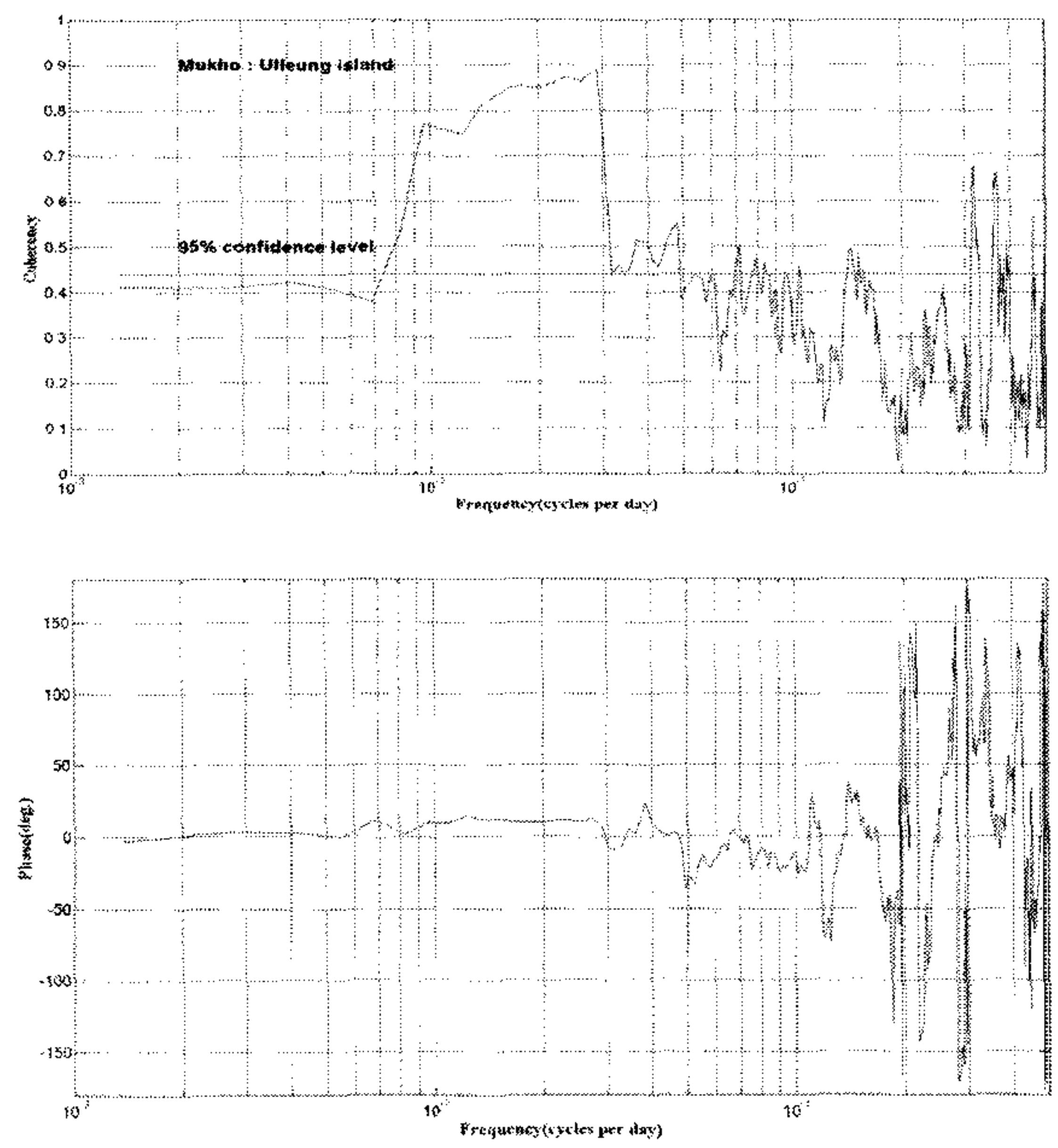

Fig. 6. Coherence(upper) and phase(bottom) relation of sea level between Mukho and Ulleung island from altimeter data.

Estimates of coherence and phase, analyzed between Mukho coast and Ulleung island from altimeter data, are shown in Fig. 6. Coherence measures the linear time-invariant relationship between two time series and phase indicates whether one time series leads or lags the other. For periods above 20.9days, coherences between the time series are found to be higher than 95% confidence level, and the phase differences are near zero.

Coherence analysis shows that they are highly coherent with near zero phase difference above at the frequency of 20.9day. The phase demonstrates that the sea levels at both places oscillate coincidently at every frequency above 20.9days.

Because the sea levels at both places can't be compared geodetically, annual mean values of sea level are calculated from the demeaned values of total time series for 14 years(Table 1). As a result, the annual mean of sea level is meaningful only for their every year variations.

1) Average standard deviation is 6.093 cm at Mukho coast and 10.08cm at Ulleung island for the whole period of 14 years.

2) Each annual data has ranges of 4.408cm ~ 7.773cm and 4.485~11.063cm at Mukho coast and Ulleung island.

Table 1 Mean ± std of sea levels at Mukho coast and Ulleung island

	Mukho coast(mean±std)	Ulleung island(mean±std)
1993	-0.540 ± 4.762	-6.538 ± 6.177
1994	-0.500 ± 6.771	-4.932 ± 6.345
1995	-0.937 ± 5.869	0.217 ± 4.485
1996	-0.610 ± 5.000	-4.819 ± 8.853
1997	0.749 ± 4.918	-2.685 ± 10.14
1998	0.725 ± 4.408	1.964 ± 7.713
1999	2.638 ± 6.144	8.868 ± 10.218
2000	2.092 ± 5.464	6.757 ± 4.742
2001	3.813 ± 7.773	3.288 ± 10.729
2002	4.763 ± 6.186	0.437 ± 8.957
2003	3.573 ± 6.273	3.911 ± 13.758
2004	3.916 ± 4.898	4.372 ± 8.152
2005	-0.284 ± 5.111	3.508 ± 11.063
2006	-1.896 ± 6.335	6.910 ± 10.602

4. SUMMARY AND DISCUSSIONS

The trend of sea level in the East Sea is rising 4.16 ㎜/yr and indicate that it rose 5.82 ㎝ in 2006 against to 1993. The South Sea is the fastest in the study areas (4.89 ㎜/yr, 6.84cm) and the Yellow Sea is 4.10 ㎜/yr and 5.75cm.

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