Sea surface circulation and its variability in the North East Asian Seas by remote sensing (Topex/Poseidon)

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Abstract

Altimeter data from the Topex/Poseidon (T/P) were analyzed to study the sea surface circulation and its variability in the North East Asian Seas. Long term averaged T/P sea level time series data where compared with in situ sea level measurements from a float-operated type tide gauge around of south Korea and Japan. T/P data are a large contaminated by 60-day tidal aliasing effect, very near the alias periods of M2 and S2. When this 60-day effect is removed, the data agree well with the tide gauge data with 4.6 cm averaged RMS difference. The T/P derived sea level variability reveals clearly the well-known, strong current-topography such as Kuroshio. The T/P mean sea level of North Pacific (NP) was higher than Yellow Sea (YS) and East Sea (ES). The T/P sea level variability, with strong eddy and meandering, was the largest in eastern part of Japan and this variability was mainly due to the influence of bottom topography in Kuroshio Extension area.

Key Words : Tidal aliasing, Sea level, Sea surface circulation

I. Introduction

Lately the augmentation of the concentrations of greenhouse gases due to the human activities is gradually increasing to the greenhouse effects, and modifies oceanic climate as ocean circulation, sea level and cycle of CO2, etc. Therefore, it is necessary to monitor the ocean under Earth Observing System by the satellite(Cess and Glazman, 1981). In this historical background, there are many observations of satellite from space to monitor the world ocean. Especially, altimetric data from satellite give very efficient informations for the studies about dynamic phenomena. Many excellent results have been accomplished in such fields of science by using very good quality data during several years (cf: Topex/Poseidon Special Issue, J. of Geophys. Res., 1994 and 1995).

Altimeter measurement(Fig. 1) have to be corrected by the environmental correction factors in order to gain the exact distance because radar waves (microwaves) propagate through every the atmospheric layers and were modified on sea surface(Yoon, 1997). There are 2 domains that have various environmental corrections factors: the atmospheric and oceanic factors. Here, the aim of our study is essentially limited to know characteristics of the inverted barometer effects as atmospheric factor, the tidal aliasing as oceanic factor, the comparison T/P sea level of Tide gauge sea level, the mean sea level and the sea level variability, respectively, in the North East Asian Seas.

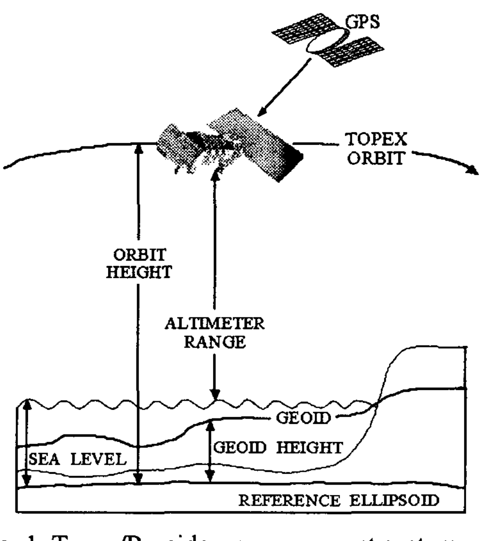

Fig. 1. Topex/Poseidon measurement system.

II. Data and Method

We use here Topex/Poseidon (T/P) altimeter data, from October 1992 to December 1998, to investigate the long term averaged sea level variation and its variability in the North East Asian Seas. The research area is composed of 3 basin scale oceans, Yellow Sea (YS), East Sea (ES) and North Pacific (NP). These area have a very big tide and complicated tidal system and about 7% of the total global tidal energy is lost in YS(Choi, 1980). If we want to study the characteristics of these oceans with T/P data, firstly the tidal aliasing errors were deleted using proper filtering method.

Merged T/P geophysical data records (GDR-M) produced from the Archiving, Validation, and Interpretation of Satellite Data in Oceanography (AVISO) Center were selected over the entire east Asian Marginal seas (115° ~ 155°E, 20° ~ 50°N) and cycles 2 to 230 covering a period from October 1992 to December 1998 (Fig. 2). Prior to the procedure of the dynamic height evaluation, all of the geophysical corrections(AVISO, 1992) and recommended editing criteria(CNES, 1994) were applied. The fully corrected sea surface heights were referenced to the GDR-M-supplied Ohio State University (OSU) 91A geoid(Rapp *et al.*, 1991).

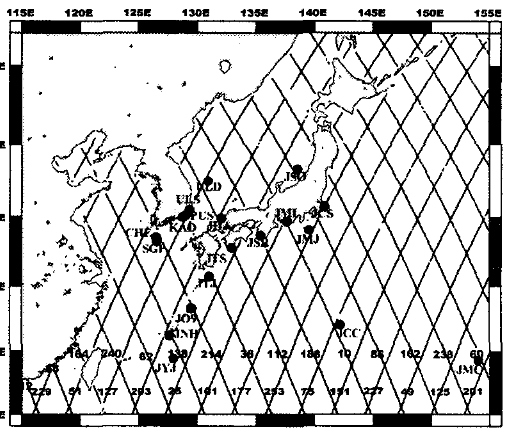

Fig. 2. Topex/Poseidon ground tracks in the North East Asian Seas. The float-operated type tide gauge location is indicated by circles.

III. Results and Discussion

1. Comparison of T/P sea level with Tide Gauge sea level

After several tests with different filtering method applied to the altimeter data, we found to yield a good representation of the float-operated type tide gauge data. T/P data are a large contaminated by 60-day tidal aliasing effect, very near the alias periods of M2 and S2(Park and Lucien, 1995). These 60-day effects are removed by 15-day filtering and Fourier reconstruction for the period is longer than 200 days. The inverted barometric correction was excluded to compare the float-operated type tide gauge data.

Hourly sampled tide gauge data have previously undergone a harmonic analysis, and predicted short-period tides (diurnal, semi-diurnal, shallow water constituents, and Seasonal variations of M2 (i.e. MA2 and MB2) were subtracted from the data. The resulting anomaly time series were smoothed and re-sampled at 1-day intervals using the same 15 days filtering, and reconstructed by Fourier reconstruction as T/P data. The T/P altimetric data give a good reproduction of the tide gauge data observed surface elevation at all stations. The mean error and RMS differences are shown in Table 1.

St.	KAD	SGP	JSR	JNH	JCS	JCC	AVG
Mean err(cm)	-2.0	0.0	0.0	0.0	0.0	0.0	-0.33
RMS err(cm)	5.6	3.0	5.5	5.4	4.8	3.3	4.6

Table 1. Mean error (ME) and root mean square error (RMSE) for T/P altimetric data and tide gauge data. The station name is shown in Fig. 2

2. Mean sea level

Fig. 3 shows the distributions of mean sea level, with the geostrophic currents and anticyclonic or cyclonic eddies at surface, in the North East Asian seas computed from T/P measurements collected over a period of 7 years. Mean sea level presents generally the plus values in the North East Asian seas excepting the southeastern coast of Hokgaido island in the North Pacific(NP), the northeast coast of Wonsan bay in the East Sea(ES) and the north coast of Bohai bay in the Yellow Sea(YS). NP is higher than YS and ES for mean sea level. Kuroshio current of NP flows northeastward and forms remarkably two anticyclonic eddies(centered at 138°E, 32°N and 1142.5°E, 35°N) with mean sea level of above 100cm and one cyclonic eddy(centered at 142°E, 32°N) with mean sea level of below 100cm in off the southeastern coast of Japan. Tsushima current of ES flows northward and forms strong anticyclonic eddy(centered at 133°E, 37.5°N) with mean sea level of above 70cm in the center of ES. Finally in the east coast of China in YS, there occur two large eddies, due to the confluence between the China Continental Coast Waters, flow southward, and the Fresh Waters from the Yellow river and the Yangts river. Then near the estuary of the Yellow river, eddy shows anticyclone with mean sea level of above 130cm(centered at 121°E, 35°N), and near the estuary of the Yangts river, eddy shows cyclone with mean sea level of below 20cm(centered at 123°E, 30°N), respectively.

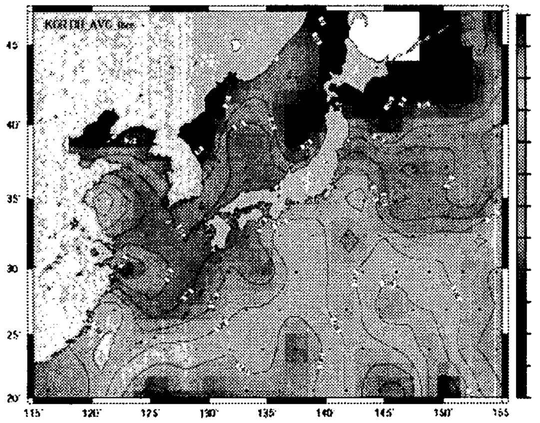

Fig. 3. Mean sea level in centimeters in the North East Asian Seas.

3. Sea level variabilities

Fig. 4 shows a map of sea level variability computed from the same method as Fig. 3. The T/P derived sea level variability reveals clearly the well-known, strong current-topography such as Kuroshio. The sea level variability, as defined here, can be considered as a statistical measure of temporal variations in major current systems. Sea level variabilities are totally strong in the east Asian marginal seas excepting the north area of ES with below 5cm. Firstly the strongest eddy activity, with sea level variability values reaching above 20cm, is confined to the eastern part of Japan, extending along 33°S to 37°S from 142°E to 154°E. Then high sea level variabilities are caused basically to eddy with the influence of meandering and bottom topography. This high eddy zone corresponds to the starting area of the Kuroshio Extension to the Eastward(Tomczak and Godfrey, 1994). Secondary variability maxima, with values exceeding 16 cm, are found in Bohai Sea centered at 39°N, 119°E in YS. The variability pattern of Inverted Barometric Effect (IBE) in YS is similar to the sea level variability and the maximum is also shown in Bohai sea. Because the gradient of IBE is a small, the other climatic effects (Monsoon, continental climate) will contribute to the sea level variability. And sea level variabilities with above 11cm, connected to eddies as Fig. 3, exist mainly along the eastern coast of China in YS. Finally in ES, sea level variabilities with above 8cm is related to Tsushima current has two branches, as the northeastward extended flow in the western coast of Japan and the northward extended flow in the southeastern coast of Korea, respectively.

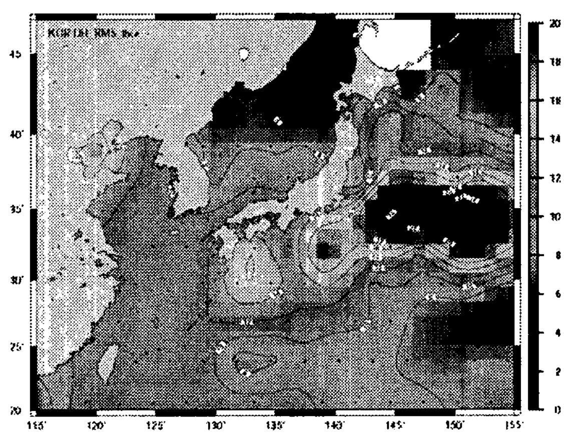

Fig. 4. Sea level variability in centimeters in the North East Asian Seas.

IV. Conclusion

The first mission data of cycles 2 through 230, from October 1992 to December 1998, was used to our study in order to investigate the comparison T/P sea level of Tide gauge sea level, and the characteristics of the mean sea level and the sea level variability in the East Asian Marginal Seas. The T/P altimetric data give a good reproduction of the tide gauge data observed surface elevation at all stations. The mean error(ME) and RMS differences(RD) are shown ME=-2.0cm and RD=5.6cm at KAD, ME=0.0cm and RD=3.0cm at SGP, ME=0.0cm and RD=5.5cm at JSR, ME=0.0cm and RD=5.4cm at JNH, ME=0.0cm and RD=4.8cm at JCS, and ME=0.0cm and RD=3.3cm at JCC, respectively. On mean sea level, the North Pacific, with two anticyclonic eddies(above 100cm) and one cyclonic eddy(below 100cm) in the Kuroshio passager, was higher than the Yellow Sea, with one anticyclonic eddy(above 130cm) and one cyclonic eddy(below 20cm) in the confluence zone between the China Continental Coast Waters and the Fresh Waters, and the East Sea, with one anticyclonic eddys(above 70cm), respectively. On sea level variability, in the North pacific, the strongest sea level variability values reaching above 20cm is confined to the eastern coast of Japan, extending along 33°S to 37°S from 142°E to 154°E. This variability was mainly due to the influence of bottom topography in Kuroshio Extension area. In the Yellow Sea, sea level variability with values exceeding 16 cm. The variability pattern of Inverted Barometric Effect (IBE) is similar to the sea level variability and the maximum is also shown in Bohai sea. Because the gradient of IBE is a small, the other climatic effects (Monsoon, continental climate) will contribute to the sea level variability. And another sea level variabilities with above 11cm exist mainly along the eastern coast of China in the Yellow Sea. In the East Sea, sea level variabilities show above 8cm in two branches of the Tsushima current passage, as one is the western coast of Japan and another is southeastern coast of Korea, respectively.

Acknowledgements

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