GEOSTROPHIC CURRENT ESTIMATION FROM THE MOST RECENT MSS AND EARTH GRAVITY MODEL AROUND THE KOREAN PENINSULA

Jaemyoung CHO, Hongsik YUN, Miran LEE, Hyunjoon CHO
Dept. of Civil & Environmental Eng.
University of Sungkyunkwan
300 Cheoncheon-dong, Jangan-gu, Suwon, Gyeonggi-do 440-746, Korea
Tel: (82)-31-290-7536 Fax: (82)-31-290-7549
E-mail: geodesy@gmail.com

KEY WORDS: Mean Sea Surface Model, Sea Surface Topography, Geostrophic

ABSTRACT: Based on long-term satellite altimetry data, the mean sea surface (MSS) model for the earth is calculated using diverse data, including terrestrial gravity, ocean depth, and ocean tide data. The data for the calculation of the MSS model are observed by the earth observation satellite, and long-term observation is required to acquire the global data. The precision and accuracy of the data vary according to the observation periods and types of data. In this study, the estimation of geostrophic velocity around the Korean peninsula using the sea surface topography calculated from the most recent MSS_CNES_CLS10, DTU10MSS models and EGM2008 Earth Gravity Model.

1. INTRODUCTION

Many satellite altimeters, including Skylab, Geo-3, Seasat, Geosat, ERS-1/2, Jason-1, Envisat, and Topex/Poseidon, having been developed and launched since the 1970s, have collected diverse marine data that are widely used in many scientific areas, not only in oceanology but also in geophysics and geodesy. The mean dynamic ocean topography or sea surface topography can be calculated from the difference between the mean sea surface and the geoidal surface. It is important in determining the terrestrial form and geoid, realizing a refined earth gravity model, and estimating the current and tide. The sea surface topography has a frequency characteristic that is similar to that of the geoidal surface, mostly within a long wavelength range, which hardly changes within a 10-20km distance range. Based on the satellite altimeter, the mean sea surface (MSS) is calculated using diverse long-term data, including the earth gravity, sea depth, and tidal level data. The precision and accuracy of the data vary according to the observation periods and types of data. In this study, the altitude and gravity observation data from satellites, including Topex/Poseidon, CHAMP, and GRACE, were used. The most recently calculated MSS models (MSS_CNES_CLS10 and DTU10MSS) were used together with the geoid model that was calculated from the EGM2008 gravity model to determine the sea surface topography. Then the geostrophic current, which is a major source of the surface current, was calculated.

2. EXPERIMENT CONTENTS AND RESULTS

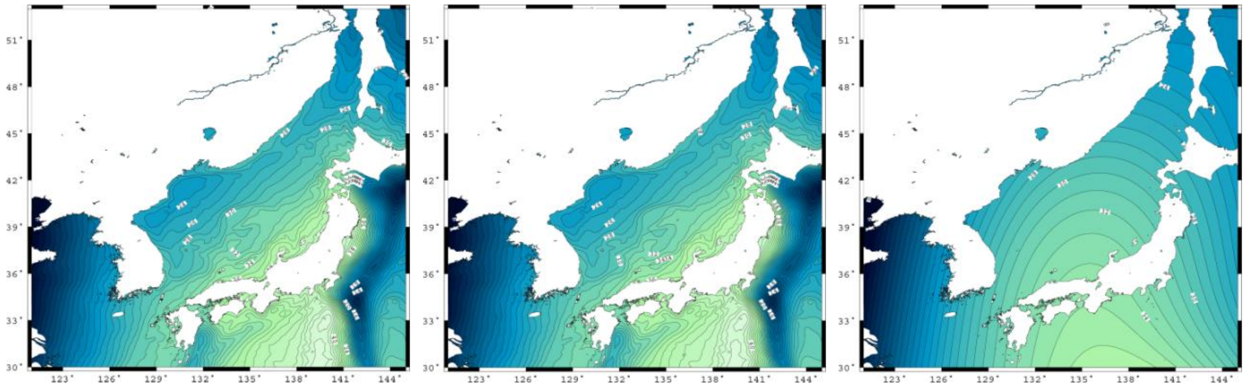
To determine the sea surface topography using the recent MSS and geoid models, two MSS models that had a 2′ interval (MSS_CNES_CLS10 and DTU10MSS) and a long-wavelength geoid model that was calculated with a maximum order of 20 degree from the EGM2008 earth gravity model were used. The geostrophic current around the Korean peninsula was determined by applying the geostrophic current flow equation, which is represented as a function of the latitude, to the sea surface topography that was determined using two MSS models.

2.1 RECENT MSS MODELS

The most recently developed MSS model, MSS_CNES_CLS10, was developed by CNES of France. It was calculated using the satellite observation data for approximately 15 years from Topex/Poseidon, ERS-1/2, etc. It has 2′-interval grid data for the 80°S - 84°N latitude area. DTU10MSS was developed by DTU of Denmark. It was calculated using the satellite observation data for approximately 13 years from ERS-1, Envisat, GOCE, etc., and it has 1′-interval grid data for the 90°S - 90°N latitude area. The difference between the results of the two MSS models around the Korean peninsula (30°N-53°N and 121°E-145°E) was 0.004 m on the average and 2.205 m at its maximum.

2.2 CALCULATION OF THE GEOIDAL HEIGHT USING THE EGM2008 MODEL

The EGM2008 earth gravity model had a maximum order of 2,190 degree, and the geoid model for determining the sea surface topography was calculated using spherical harmonics with a maximum order of 20 degree, considering the long wavelength effect. Fig. 1 (c) shows the geoid model around the Korean peninsula with a maximum order of 20 degree. The geoidal height was 23.282 m on the average, 36.793 m at its maximum, and -5.324 m at its minimum.



(a) (b) (c)

Figure 1. Around the Korean peninsula (a) MSS_CNES_CLS10 model, (b) DTU10MSS model, and (c) Geoidal height from EGM2008 model (maximum order of 20 degree)

2.3 CALCULATION OF THE SEA SURFACE TOPOGRAPHY

The sea surface constantly changes due to tides and wind, and its average does not completely coincide with the geoid. Thus, the sea surface topography is represented by the following equation.

$$\text{Sea Surface Topography (SST)} = \text{Sea Surface Height (SSH)} - \text{Geoidal Height (N)} \qquad (1)$$

Fig. 2 shows the sea surface topography distribution that was calculated using the geoid model with a maximum order of 20 degree and the two MMS models.

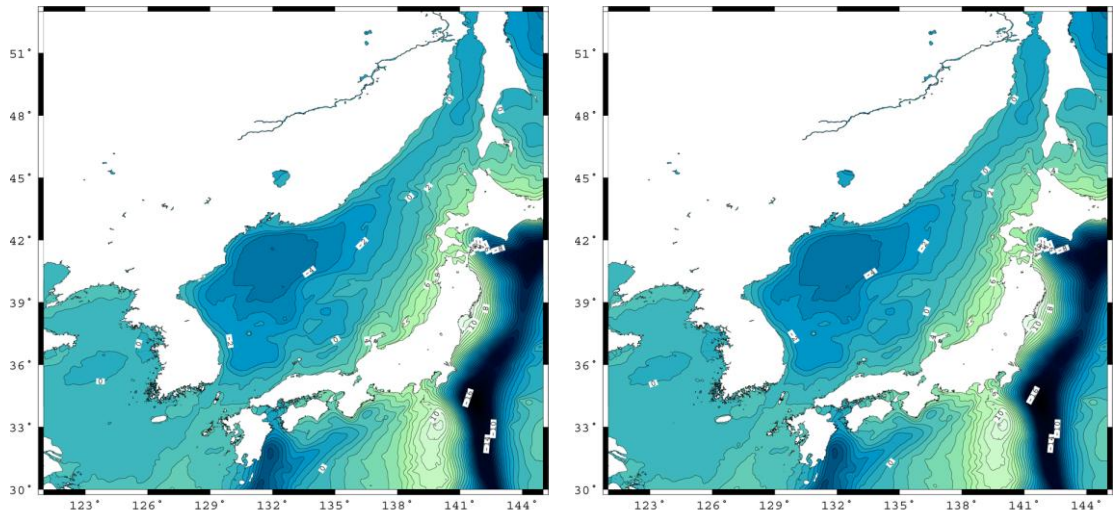


Figure 2. Sea surface topography that was calculated using the MSS_CNES_CLS10 model(L) and the DTU10MSS model(R)

2.4 CALCULATION OF THE GEOSTROPHIC CURRENT

The geostrophic current flow equation can be expressed as follows, assuming that the horizontal speed is higher than the vertical speed, the frictional force is very small, and the gravitational force is the only external force:

$$u = -\frac{1}{fp}\frac{\partial p}{\partial y} \quad , \quad v = \frac{1}{fp}\frac{\partial p}{\partial x} \tag{2}$$

Where, f=2ΩsinΦ(f : coriolis parameter, Ω : earth's angular rotation speed(=7.29X10^{-5}rad/sec), Φ : latitude)

Eq. 2 was applied to the sea surface topography that was calculated using the MSS and geoid models to determine the speed component in the latitude/longitude direction and to express the geostrophic currents as vectors (Fig. 3). The geostrophic current around the Korean peninsula was 2.530 m/sec on the average and 13.938 m/sec at its maximum in the MSS_CNES_CLS10 model, and 2.597 m/sec on the average and 13.771 m/sec at its maximum in the DTU10MSS model. The geostrophic current was very slow in the West Sea, but it was very fast in the East Sea because of the inflow from the Russian and Chinese coasts and the outflow towards the Japanese coasts.

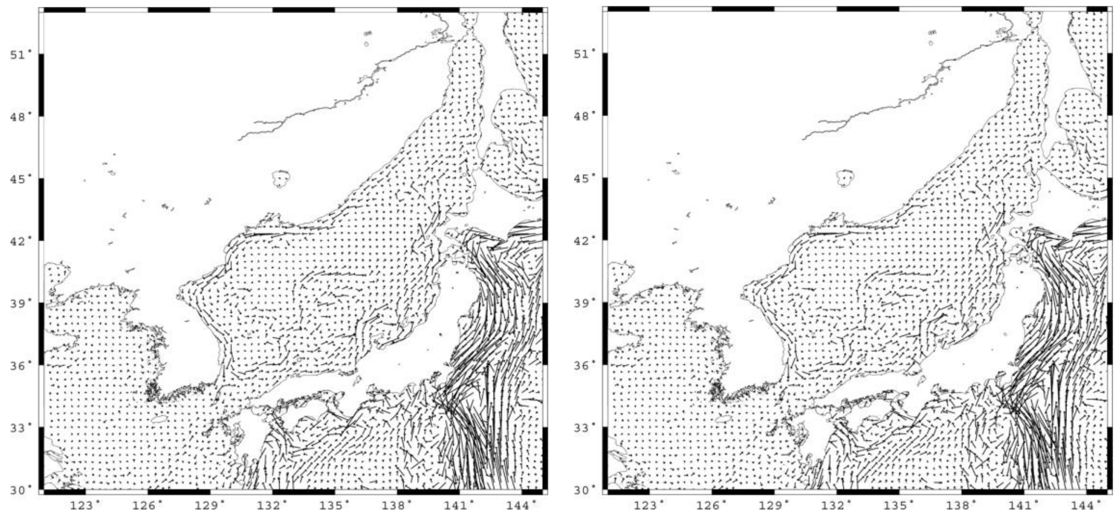


Figure 3. Geostrophic current that was calculated using the MSS_CNES_CLS10 model(L) and the DTU10MSS model (R)

3. CONCLUSION

In this study, the MSS models based on the recent satellite observation data (MSS_CNES_CLS10 and DTU10MSS) and a geoid model that was calculated with a maximum degree of 20 from the EGM2008 earth gravity model were used to calculate the sea surface topography and the geostrophic current around the Korean peninsula. The sea surface topography around the Korean peninsula was 0.329 m (±3.593 m) on the average. The slope was relatively gentle in the West Sea, but steep in the East Sea. The geostrophic current was very slow with no special trend in the West Sea, but relatively fast in the East Sea, flowing counterclockwise through the coasts of Russia, China, Korea, and Japan. It is expected that more detailed ocean current motion can be estimated by combining these geostrophic current data with marine data, which will be used as basic data in the navigation and fishing industries.

References

H. S. Yun and D. H. Lee, 2006, Estimation of Geostrophic Current Calculated from Sea Surface Topography in East Sea, Korean Journal of Geomatics, Vol. 24, No. 2, pp. 159-165.

H. Hwang, H. S. Yun and D. H. Lee, 2008, Determination and Analysis of Sea Surface Topography for Unification of Vertical Datum in East-Asia Area, Korean Journal of Geomatics, Vol. 26, No. 3, pp. 207-217.

Featherstone, W. E., 2002, Expected Contributions of Dedicated Satellite Gravity Field Missions to Regional Geoid Determination with some Examples from Australia, Journal of Geospatial Engineering, Vol. 4, No. 1, pp. 1-19.

Poutanen M., 2000, Sea Surface Topography and Vertical Datums using Space Geodetic Techniques. Doctoral thesis, University of Helsinki. Also in : Publications of Finnish Geodetic Institute, pp. 128.