Bathymetry Estimation Using the Gravity-Geologic Method in High Latitude Areas

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Reference

- Hsiao, Y. S., J. W. Kim, K. B. Kim, B. Y. Lee, and C. Hwang, 2011: Bathymetry estimation using the gravity-geologic method: An investigation of density contrast predicted by the downward continuation method. Terr. Atmos. Ocean. Sci., 22, 347-358, doi: 10.3319/TAO.2010.10.13.01(Oc)

- Ibrahim, A. and W. J. Hinze, 1972: Mapping buried bedrock topography with gravity. *Ground Water*, 10, 18-23, doi: 10.1111/j.1745-6584.1972.tb02921.x.

Outline

- Introduction
- Methodology

  1. The Gravity-Geologic Method (GGM)

  2. Downward Continuation (DWC) Method
- Data of two test areas
- Discussion
- Conclusion

Introduction

- Estimating accurate bathymetry is important for understanding many of the Earth’s physical properties.
- Although shipborne sonar sounding provides better spatial resolution along shipborne tracking, coverage is severely limited.
- The gravity-geologic method (GGM) can be readily applied in estimating bathymetry in large-scale areas.

Introduction

Usually ,the density contrast between seawater and bedrock is roughly 1.64 g cm^{-3}

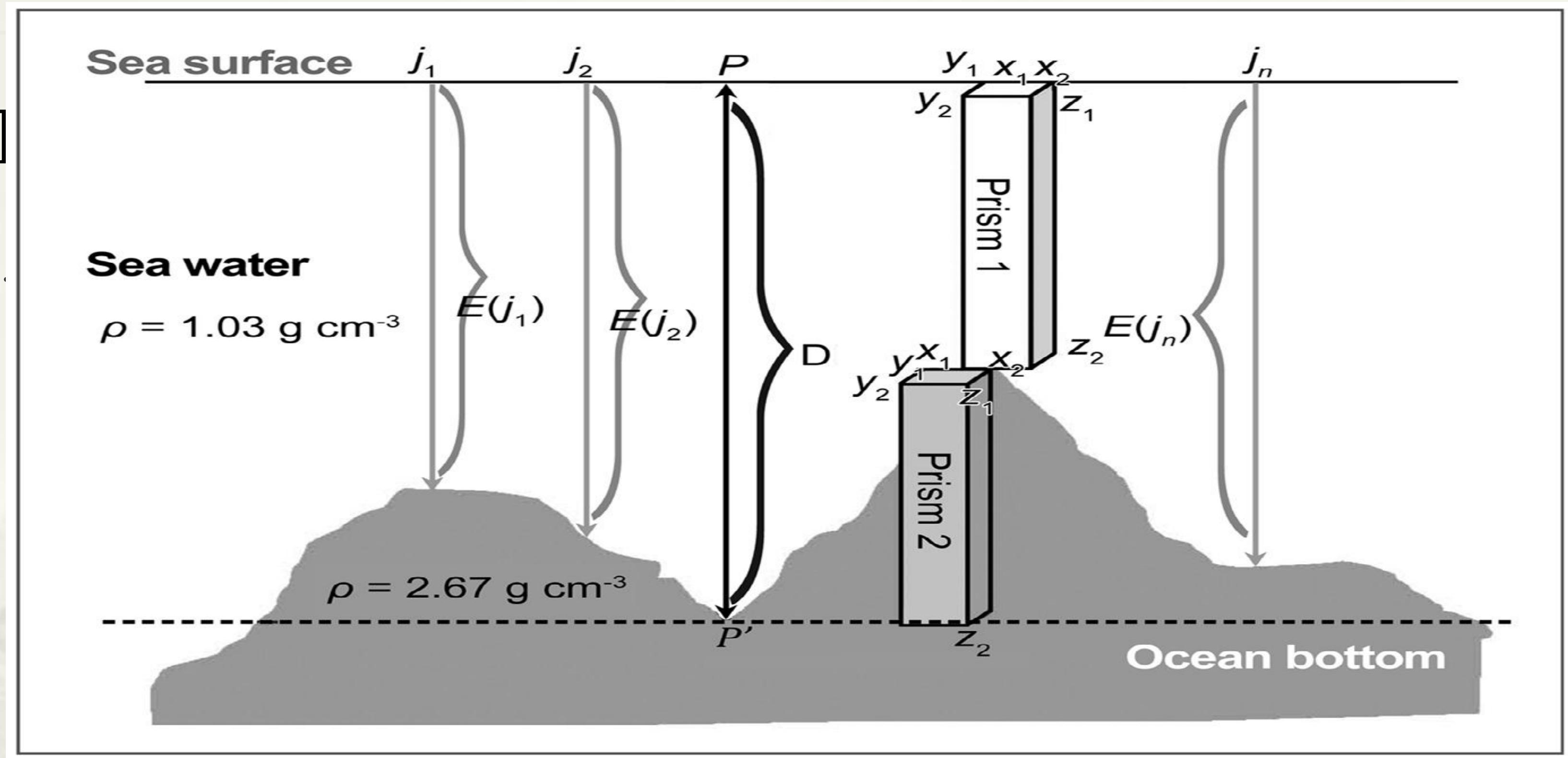
- In GGM, determination of the best density between the seawater and the ocean floor mass is a key factor for obtaining an accurate bathymetric model.
- The downward continuation (DWC) is a technique which can be determine the real density contrast.

Introduction

The process in this presentation:

1. Using GGM method to estimate bathymetry in research areas.
2. Using DWC method to estimate density contrast in research areas.
3. Results of bathymetry predictions and accuracy analyses.

Methodology



1. $\Delta g_{obs}(i) = \Delta g_{short}(i) + \Delta g_{long}(i)$
2. $\Delta g_{short}(j) = 2\pi G \Delta\rho [E(j) - D]$
3. $\Delta g_{long}(j) = \Delta g_{obs}(j) - \Delta g_{short}(j)$

Methodology

3. $\Delta g_{long}(j) = \Delta g_{obs}(j) - \Delta g_{short}(j)$

After that, $\Delta g_{long}(j)$ can be interpolated to create a grid of the long-wavelength gravity field, $\Delta g_{long}(i)$

4. $\Delta g_{short}(i) = \Delta g_{obs}(i) - \Delta g_{long}(i)$

5. $$E(i) = \frac{\Delta g_{short}(i)}{2\pi\rho G} + D$$

where E(i) is a grid of an estimated bathymetric model estimated by GGM.

Methodology

Downward Continuation (DWC) Method:

- The factors influencing the accuracy of the GGM bathymetric model include the density contrast $\Delta\rho$.
- The values of density contrast $\Delta\rho$ mentioned would be determined by downward continuation (DWC).

Methodology

Downward Continuation (DWC) Method:

$$G_{h1}(f_x, f_y) = e^{2\pi\Delta h_{12}\sqrt{f_x^{\,2}+f_y^{\,2}}}\, G_{h2}(f_x, f_y)\, F(f_x, f_y)$$

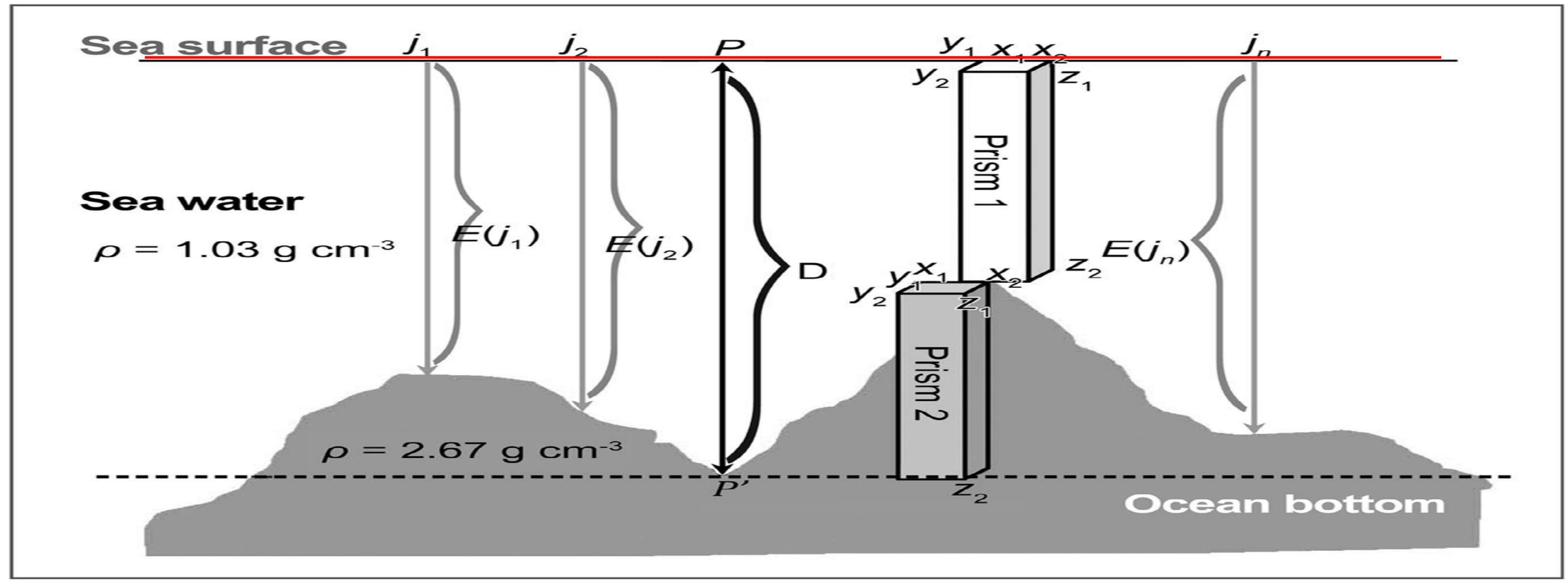
where $F(f_x, f_y)$ is a low-pass filter in the wavenumber domain.

$G_{h1}(f_x, f_y)$ and $G_{h2}(f_x, f_y)$ denote the two-dimensional Fourier transforms of the gravity field at h1 and h2, respectively; fx and fy represent the horizontal frequency in x and y components, respectively; and, Δh_{12} = h2 - h1

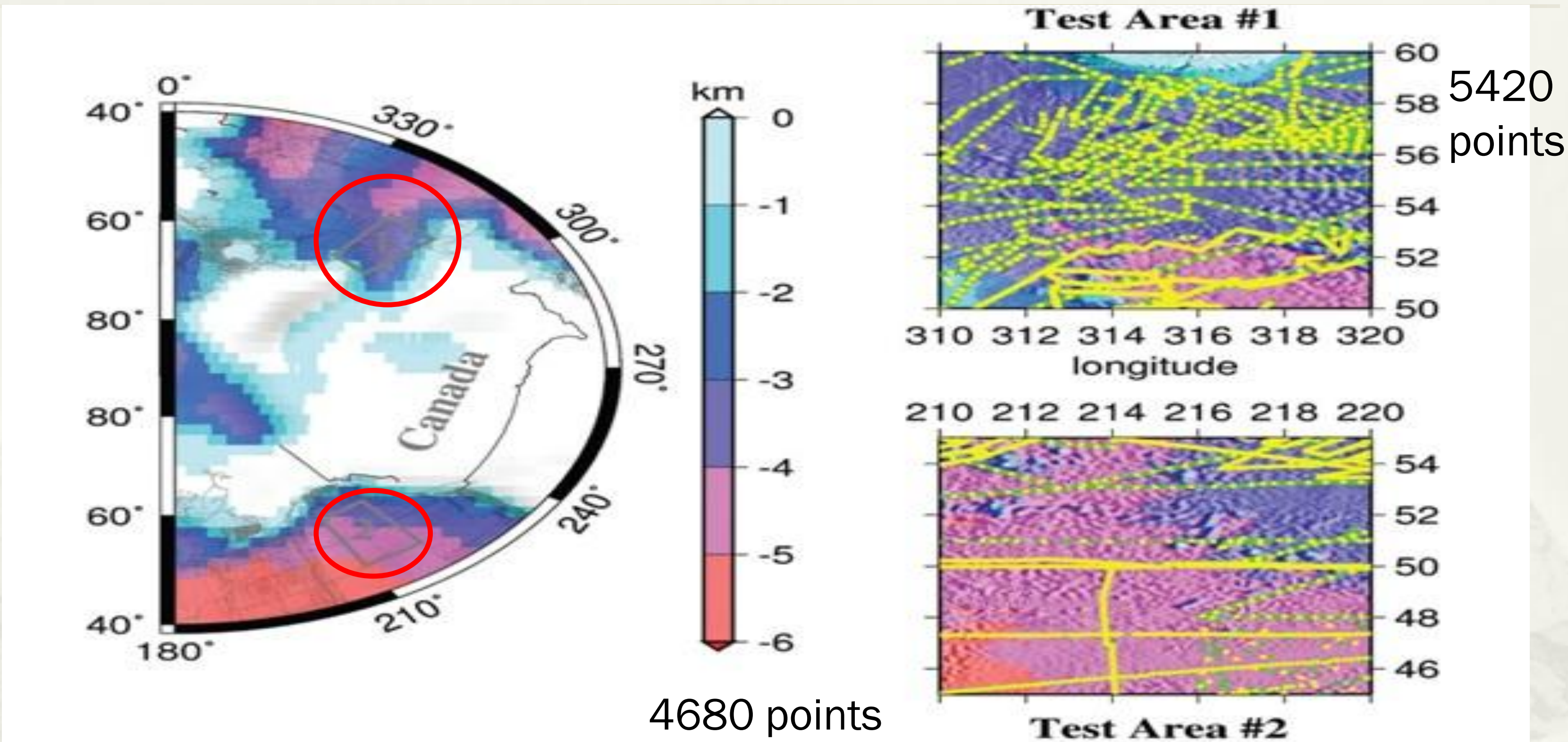
Methodology

Downward Continuation (DWC) Method:

The total topographic effect is obtained by summing the contributions from all prisms. The topographic gravity effect at P is removed prior to the DWC computation, and the topographic gravity effect at P' is then restored to achieve downward-continued gravity.



Data of test areas

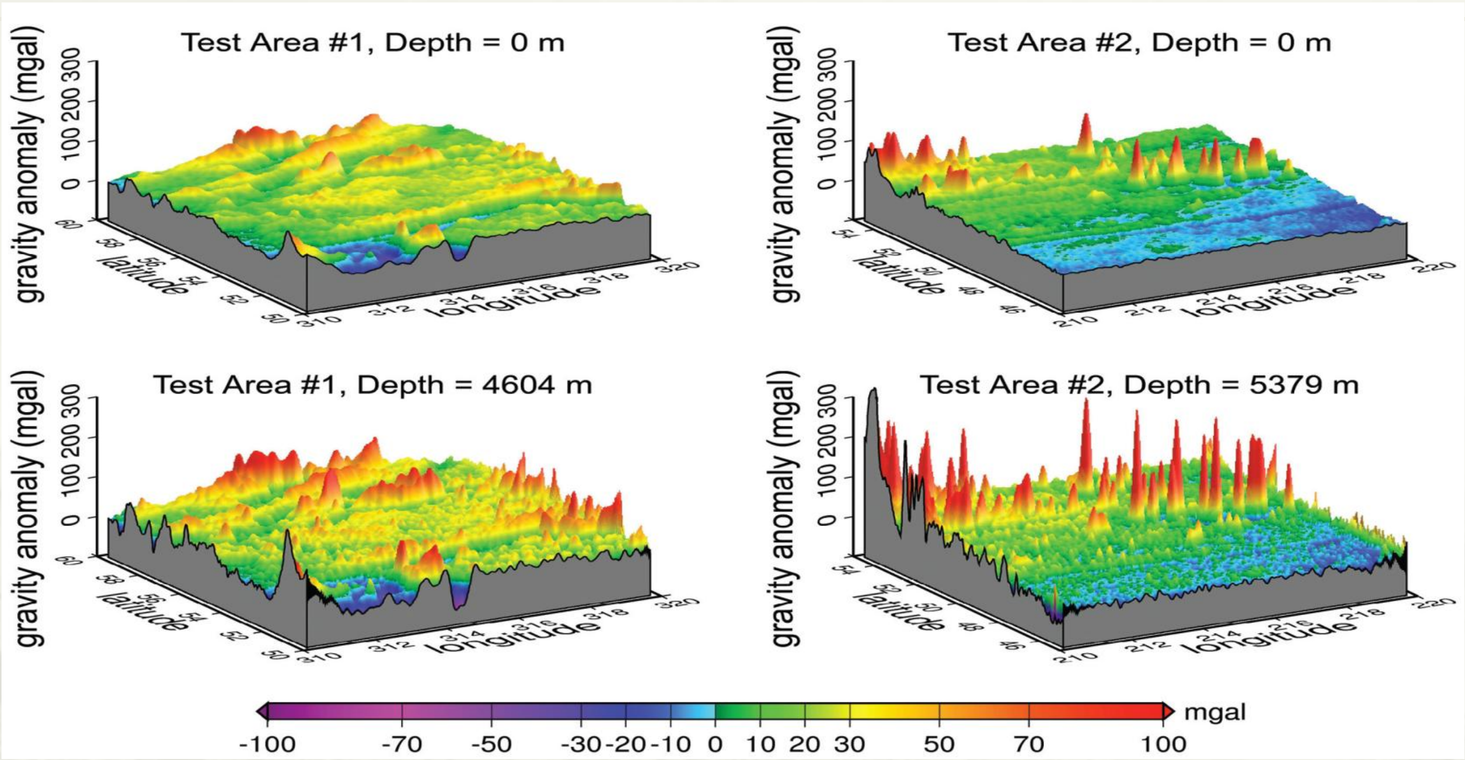


Test Area #1 is located south of Greenland between 40 - 50°W and 50 - 60°N.

Test Area #2 is located south of Alaska between 140 - 150°W and 45 - 55°N.

Green and yellow dots denote the control and check points, respectively. The control points were used to create a long-wavelength gravity field in GGM [Eq. (2)], and the check points evaluated the accuracy of the bathymetric estimates.

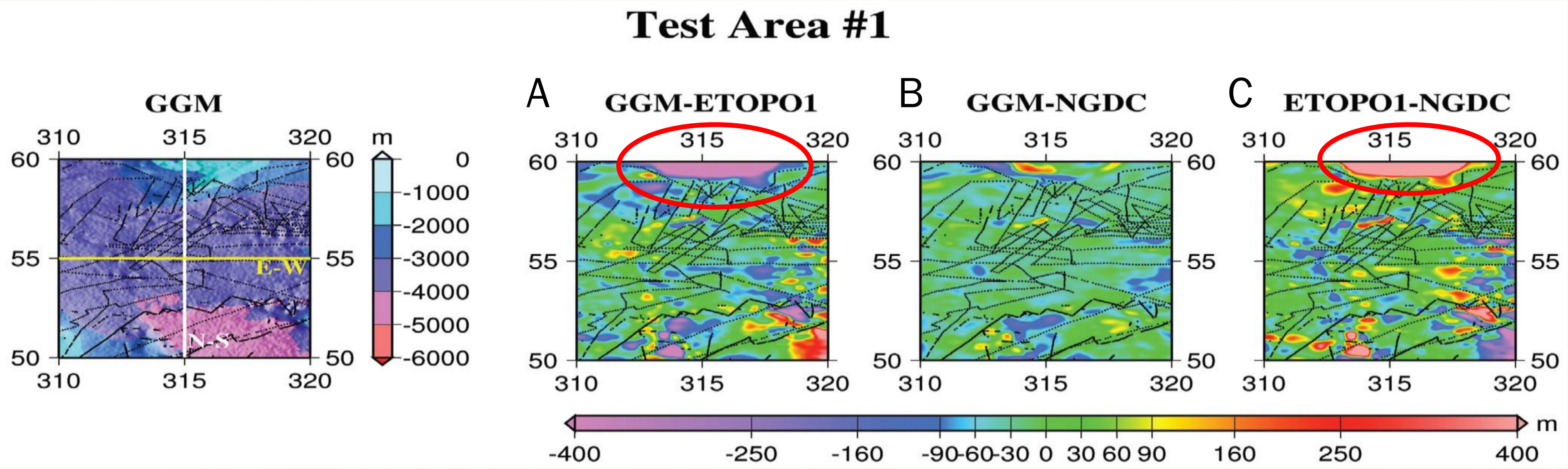
Discussion (Using DWC method)



Comparing the scales of the two fields in Test Areas #1 and #2, $\Delta\rho$ = *1.47 g cm^{-3} for Test Area #1 and 1.30 g cm^{-3} for Test Area #2* respectively.

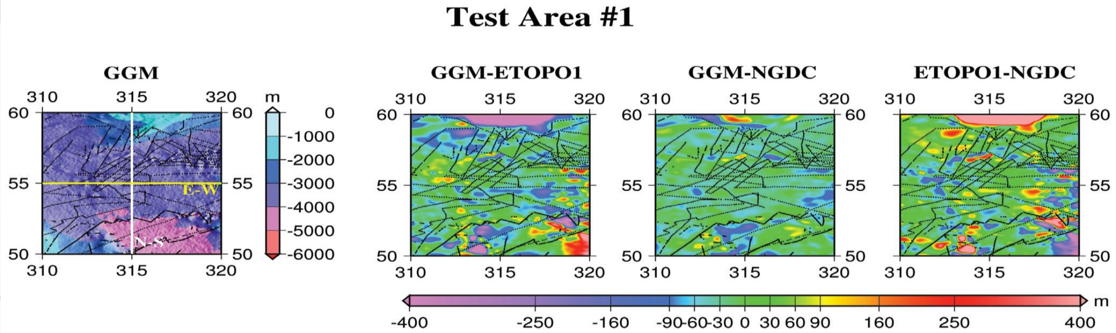
The predicted density contrasts were both smaller than the geologically reasonable density contrast of 1.64 g cm^{-3}.

Discussion



The huge differences in values over the area#1 can reach approximately ±900 m. A large part of these significant differences can be attributed to the steep sea topography and sparse ship-derived data.

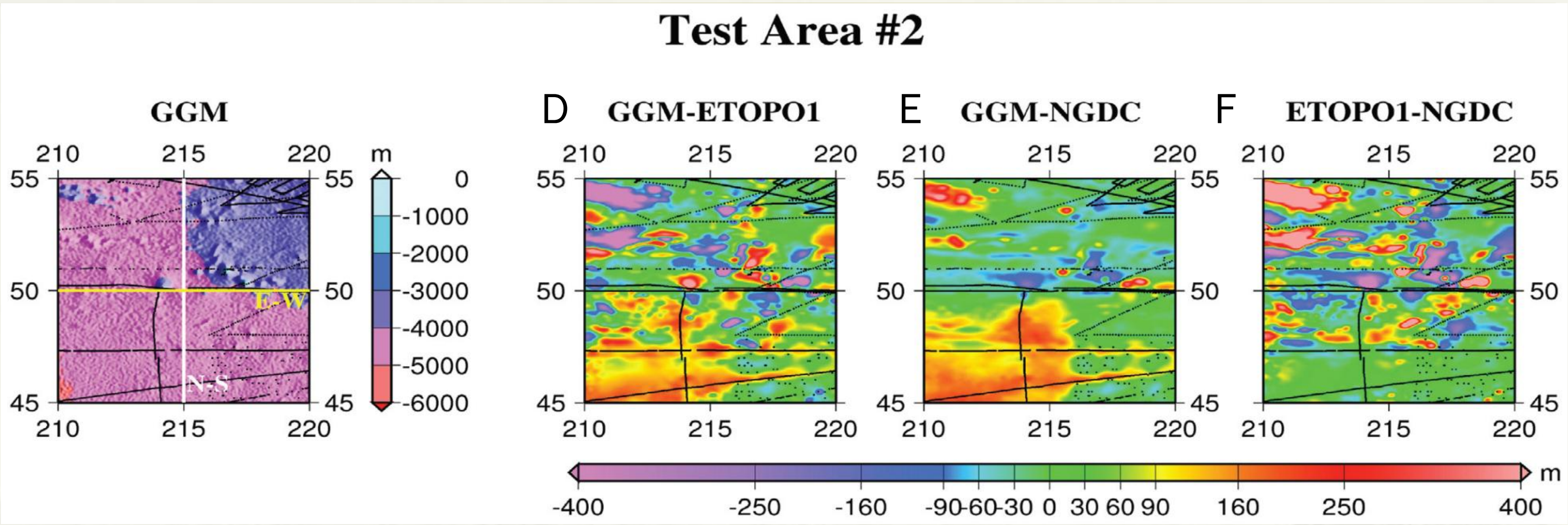
Discussion



Models	Max	Min	Mean	Std Dev
GGM - ETOPO1	435.7	-934.1	-46.4	229.6
GGM - NGDC	230.1	-264.2	12.2	39.4
ETOPO1 - NGDC	918.4	-501.4	41.3	245.0

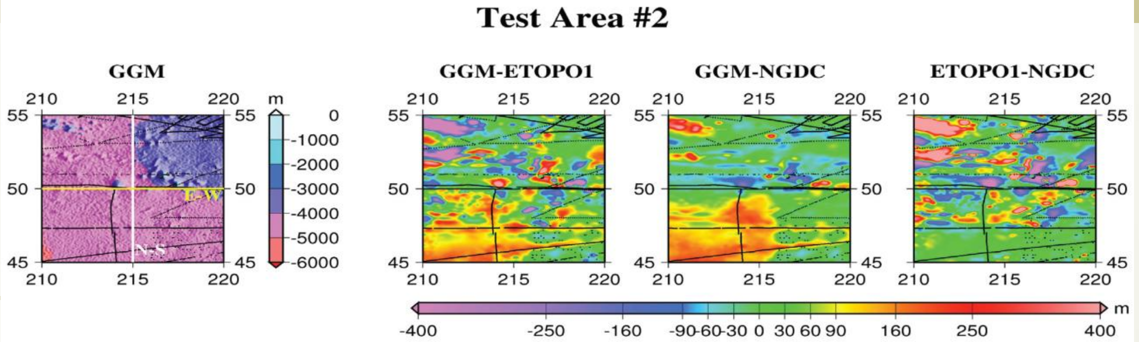
- The differences indicating that the results of the GGM model were much closer to those of the NGDC model.

Discussion



The bed-distributed ship-derived data were the key factor causing the huge differences in Test Area #2.

Discussion

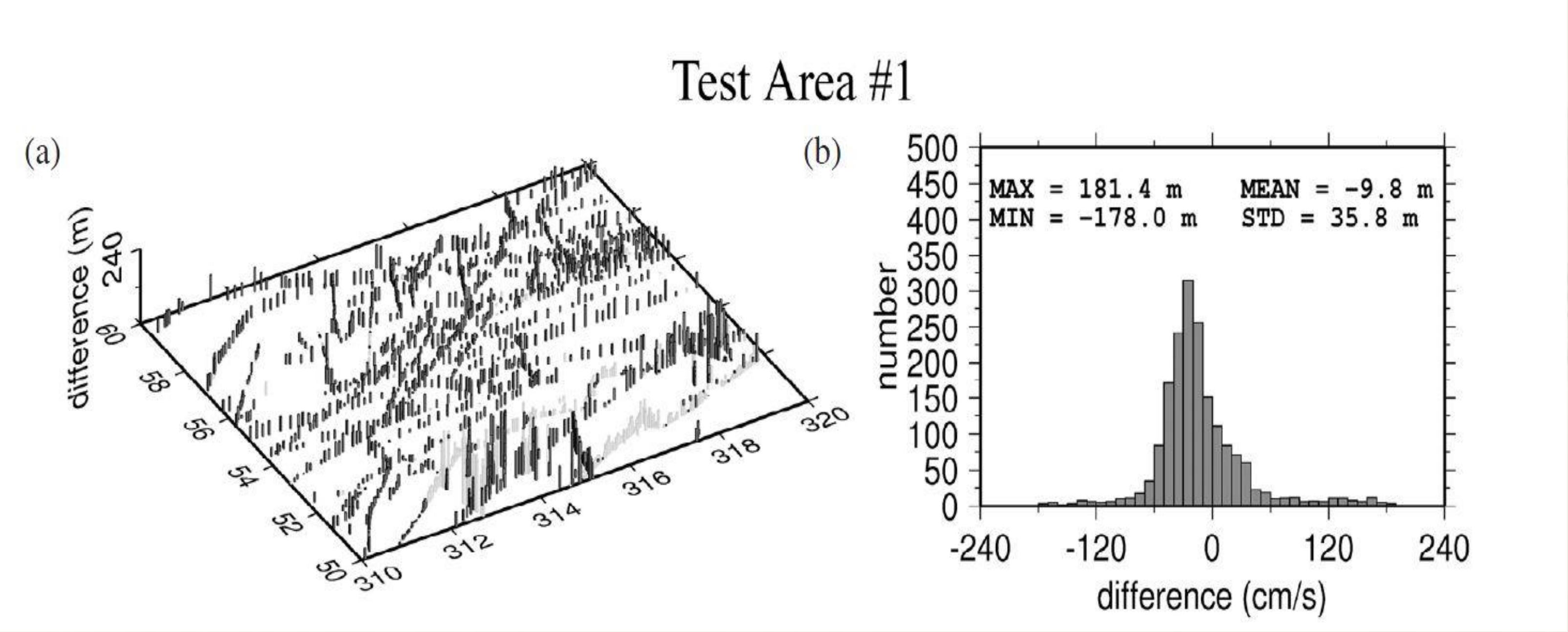


Models	Max	Min	Mean	Std Dev
GGM - ETOPO1	311.4	-896.4	10.6	156.6
GGM - NGDC	471.0	-239.7	36.8	82.2
ETOPO1 - NGDC	818.3	-278.6	18.3	177.7

- In the area #2, the differences between the GGM and NGDC models and the GGM and ETOPO1 models reached approximate standard deviations of 82.2 and 156.6 m, respectively.

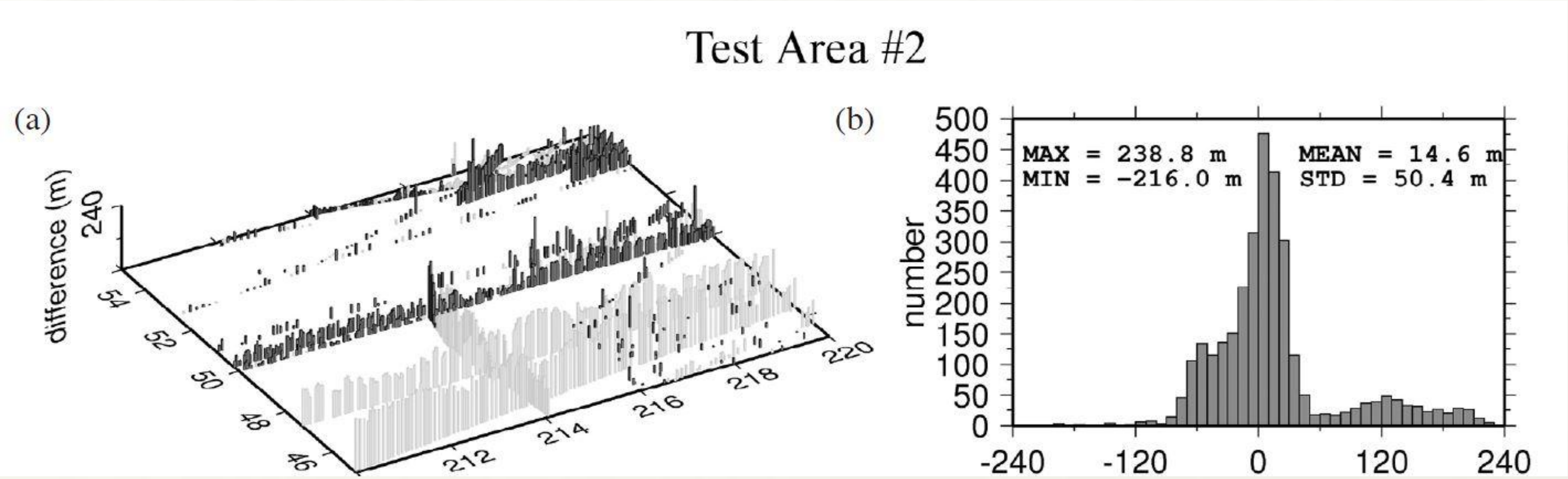
Discussion

- The accuracy of the GGM prediction in Test Area #1 was within the range of 20 ~ 40 m, due to standard deviation agreement at 35.8 m.



Discussion

- The same as Test Area #1. However, accuracy of the range of 20 ~ 40 m for the GGM prediction was not achieved in Test Area #2, due to a standard deviation of 50.4 m.



Discussion

- In general, the GGM predicted bathymetric model in Test Area #1 was more accurate than in Test Area #2, the reason why GGM performed well in Test Area #1 was due to a more even distribution of shipborne measurements.

Discussion

Case	Test Area	density contrasts (g cm^{-3})	Max	Min	Mean	Std ev
1	#1	1.64 (assumed)	177.5	-189.2	-10.3	38.2
2	#2	1.47 (predicted)	181.4	-178.0	-9.8	35.8
3	#1	1.64 (assumed)	249.1	-204.7	16.8	54.2
4	#2	1.30 (predicted)	238.8	-216.0	14.6	50.4

Considering predicted density contrast enhances the accuracy of approximately 4 m.

Conclusion

- The downward continuation (DWC) method was used to determine the effective density contrast between the seawater and the ocean bottom topographic mass, in order to accurately estimate bathymetry using the gravity-geologic method (GGM) in two study areas.

- The GGM prediction in Test Area #1 turned out to be more accurate than in Test Area #2, due to denser and better distributed shipborne measurements in Test Area #1.

Conclusion

- The consideration of predicted density contrast can make an enhancement of approximately 3 ~ 4 m for the GGM.
- Although GGM with properly estimated density contrasts can be effective in predicting large-scale bathymetric coverage from limited shipborne measurements, sparse shipborne measurements can be still a problem for GGM predictions.

THANK YOUR LISTENING~