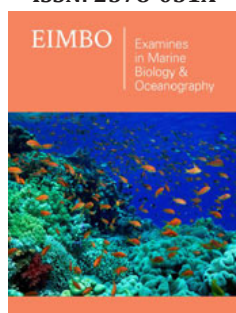


Stochastic Analysis of Random Heterogeneity of Bathymetry at Gulf of Mexico

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Abstract

The fine-scale bathymetry at the Gulf of Mexico has been measured. I use a stochastic analysis to characterize the random heterogeneities of the bathymetry. The randomness regionally corresponds to the marine geology in the area such as salt deposits, and I also suspect that the ocean loop current influences the local randomness and its directionality. The resolution of the bathymetry is about 15m, which is much higher than other sea and gulfs. This provides a unique opportunity to study the relationship between the bathymetry and geology, ocean current, heat flow, biology, and chemical components.

Opinion

Seafloor topography (bathymetry) is not well known compared to the land topography because our geodesy equipments, for example GNSS/InSAR, do not work below thick water. Our understanding of land surface of the Moon is better than the Earth's ocean floor. However, importantly, the bathymetry influences ocean current [1], geology [2], heat flow [3,4] and biological diversity [5]. The bathymetry at the northern Gulf of Mexico has been measured very well because of the oil and gas production and its 3D seismic surveys.

The Bureau of Ocean Energy Management (BOEM) released the detailed bathymetry grid in 2016 (Figure 1a); [6]. The grid size is $12.1 \times 12.1 \text{ m}^2$ ($40 \times 40 \text{ ft}^2$) and the bathymetry covers more than 230000 km^2 . The average horizontal resolution of the bathymetry is roughly 15m, and the uncertainty of the depth is 1.3%. Because the resolution of a typical global model is around 900m (SRTM30_PLUS) [7] this BOEM grid has much higher lateral resolution. This grid provides us an interesting opportunity to study the detailed bathymetry and its relationship to various physical, chemical, and biological phenomena. The rough seafloor surface at -96W - -90W is prominent, and this deformation is largely due to the migration and dissolution of the deep salt deposits [8]. This structure is stopped at the Sigsbee Escarpment, where the south end of the colored topography area is in Figure 1a. Another slope on the east side, which is smoother, is called West Florida Escarpment. In the middle (right west of Box III), the Mississippi canyon exists, which was created by the Mississippi river when the sea level was low. I use a stochastic approach similar to [9] to understand the random heterogeneities of the ocean floor in Figure 1a. For a random medium, anisotropic autocorrelation functions can represent the stochastic nature of the medium [10]. This approach has been used to numerically model the bathymetry with different characteristic functions [11,12].

I select three areas (I, II and III) and compute the 2D Fourier transform and power spectra density function (PSDF) of them (Figure 1b,1c & 1d). The bright color (high power) indicates the highly heterogeneous media. Interestingly, the directions of heterogeneity vary at different locations. In Areas I and II, ocean topography is heterogeneous in the NW-SE and NE-SW directions, respectively. In Area III, the topography has no preferential directions. I speculate that this pattern in Area III is due to the loop current entering through the Yucatan Channel [13]. The size of Area III is large and contains different directions of heterogeneities.

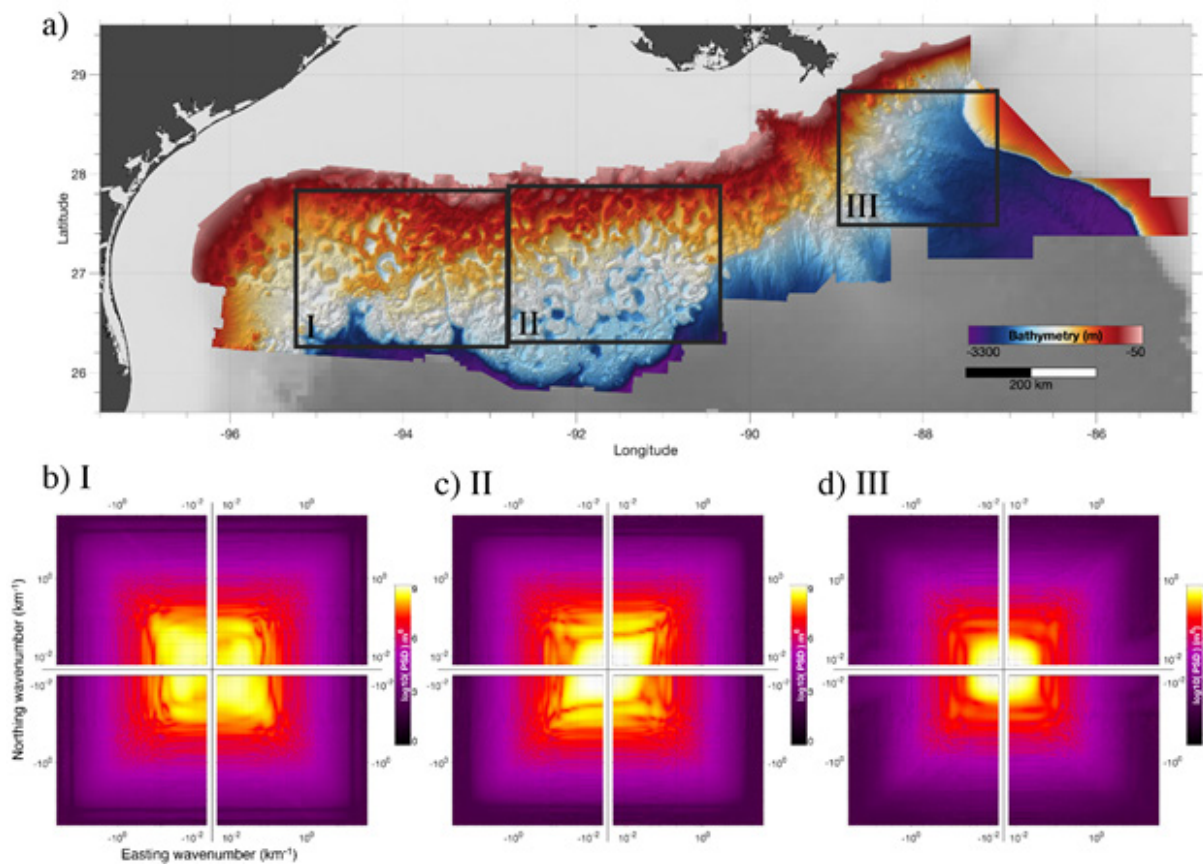


Figure 1: Bathymetry of Gulf of Mexico Colored area [6] (Figure a). The background gray image shows the bathymetry provided by ETOPO2. The boxes represent the areas used for the stochastic analyses. The size of Boxes I and II is $170 \times 242 \text{ km}^2$ and for Box III $145 \times 182 \text{ km}^2$ (Figure b, c & d). The power spectra density of the random heterogeneities at each box in Panel (Figure a) and the top-left Roman numbers indicate the location. The axes are in the logarithmic scale, and hence the data points of wave number 0 are not shown.

When I fit the PSDF using von Karman model, I can measure the autocorrelation length of the randomness, which represents the randomness [14,15]. In Area I, because the medium has anisotropic randomness, two autocorrelation lengths are important, and the short and long lengths are 9 and 25km, respectively. Area II is also anisotropic, and short and long lengths are 17 and 50km, respectively. This means that Area I contains finer structure than Area II. Area III can be represented well by an isotropic random medium with the autocorrelation length of 50km. Overall, the salt dissolved area at the north of the Sigsbee Escarpment has small-scale heterogeneities than eastern areas. The random characteristics of bathymetry estimated here should be compared to other data such as geology, ocean current, geo and ocean-chemistry and biology. The fins-scale bathymetry grid is a unique opportunity to study local-scale correlations between them[16].

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