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3D marine geomorphometry for the Arctic Ocean

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Abstract—**We develop a system for three-dimensional (3D) geomorphometric modeling of the Arctic Ocean submarine topography. Previously, low-resolution desktop versions of the system were created. In this article we present some results of the next stage developing multiscale, desktop and web versions of the system. We utilize a 500-m gridded digital elevation model (DEM) of the Arctic Ocean floor and adjacent land territories from the International Bathymetric Chart of the Arctic Ocean (IBCAO) ver. 3.0. To process, visualize, and operate the data, the following software are used: (1) Blender 2.79b, an open-source software for 3D modeling, rendering, and animation; (2) BlenderGIS addon for importing and processing geospatial data; (3) LandLord, a software for calculating geomorphometric variables; and (4) Verge3D, a toolkit for creating immersive web-based experiences. The main steps of the data processing are: (a) geomorphometric calculations; (b) importing the IBCAO DEM and morphometric models into Blender; (c) 3D modeling; and (d) exporting the 3D models into the web. A final version of the system will provide: Storage of the DEM of the Arctic Ocean floor; (2) Storage of models for 18 morphometric variables derived from the DEM; (3) Interactive, real-time 3D visualization of the morphometric models; and (4) Free access to this information via Internet.**

I. INTRODUCTION

Submarine topography is one of the major factors, which determine the course and direction of processes at the boundary between hydrosphere and lithosphere. Being a result of the interaction of endogenous and exogenous processes, submarine topography can also reflect the geological structure of a territory. Thus, bathymetric DEMs are used for solving problems of marine geomorphology, geology, and biology [1].

We develop a system for three-dimensional (3D) geomorphometric modeling of the Arctic Ocean floor [2]. Previously, low-resolution desktop versions of the system were created [3–5]. Here we present some results of the next stage of the project [6] developing multiscale, desktop and web versions of the system.

II. MATERIALS AND METHODS

As an input data, we utilize a 500-m gridded digital elevation model (DEM) of the Arctic Ocean floor and adjacent land territories from the International Bathymetric Chart of the Arctic Ocean (IBCAO) 3.0 [7, 8]. The DEM describes a territory measuring about 5,800 km × 5,800 km (Fig. 1). Depths and elevations range from –5,520 m to 5,110 m. A set of DEMs with resolutions of 1 km, 5 km, 10 km, and 15 km were extracted from the IBCAO DEM. All these DEMs are presented in the polar stereographic projection.

The main steps of the data processing are:

1. DEM smoothing. To suppress high frequency noise in the DEMs, they were smoothed.

2. Geomorphometric calculations. From the smoothed DEMs, we derived digital models of morphometric variables [9]: slope gradient, slope aspect, horizontal curvature, vertical curvature, mean curvature, Gaussian curvature, minimal curvature, maximal curvature, unsphericity curvature, difference curvature, vertical excess curvature, horizontal excess curvature, ring curvature, accumulation curvature, catchment area, dispersive area, topographic index, and stream power index.

3. Importing the IBCAO DEM and morphometric models into Blender.

4. 3D modeling. The Blender-based approach for 3D terrain modeling [10] includes the following key steps:

- Automatically creating a polygonal object from a DEM.
- Selecting an algorithm to model the 3D geometry.
- Selecting a vertical exaggeration scale.
- Selecting types, parameters, a number, and positions of light sources.
- Selecting methods for generating shadows.
- Selecting a shading method for the 3D model.
- Selecting a material for the 3D model surface.

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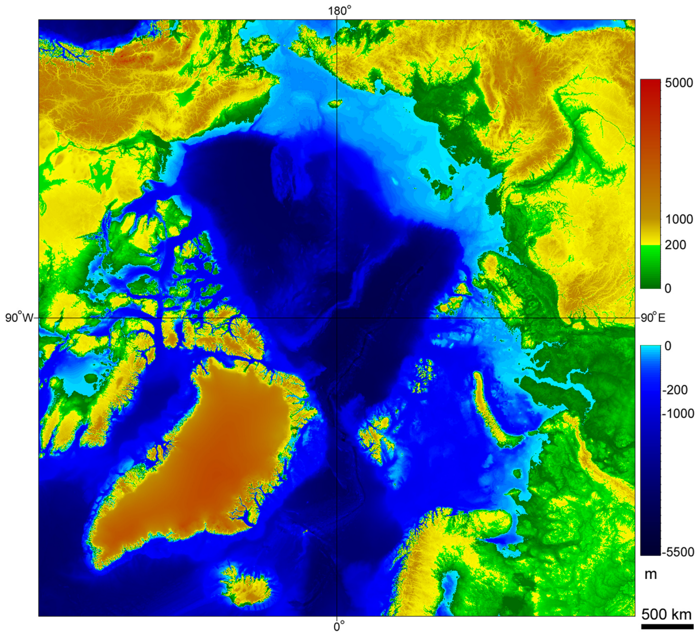

Figure 1. The IBCAO DEM: depths of the Arctic Ocean floor and elevations of adjacent regions of Eurasia and North America [3].

- Overlaying a texture on the 3D model.
- Setting a virtual camera(s).
- Rendering the 3D model.

5. Exporting the 3D models into the web.

To process, visualize, and operate the data, the following software are used:

- LandLord software for geomorphometric calculations [9].
- Blender 2.79b [11], an open-source software for 3D modeling, rendering, and animation.
- BlenderGIS addon [12] designed for import and processing of geospatial data.
- Verge3D [13], a powerful and intuitive toolkit, which allows Blender users creating immersive web-based experiences. (Blend4Web [14] and Sketchfab [15] packages may be used as alternative to Verge3D).

III. Results and Discussion

Figures 2–5 display several examples of the 3D desktop morphometric models produced from DEMs with different resolutions ranging from 1 km to 15 km. Figure 6 represents an example of a 3D online model produced from the 15 km-gridded DEM.

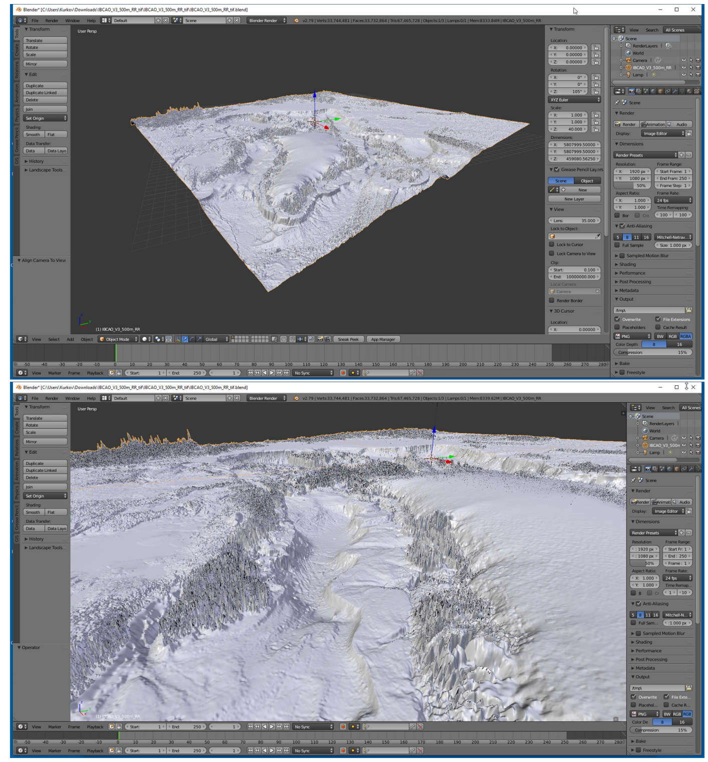

Figure 2. Examples of 1 km-gridded, 3D desktop monochromic models of the Arctic Ocean floor and adjacent regions presented within the Blender environment. General perspective view from the Atlantic (upper). Perspective view of the Buffin Bay and the Davis Strait from the Labrador Sea (lower) [6].

3D models clearly show the main features of the submarine topography manifested according to the physical and mathematical sense of a particular morphometric variable [5].

It is obvious that generalization level of the 3D model appearance depends mainly on the particular DEM resolution, although several smoothing applied to the DEMs before morphometric calculations and during 3D modeling also contribute to resulted smoothness of the models.

The created 3D morphometric models can be used in marine geomorphological, geological, and, probably, biological studies of the Arctic Ocean.

Our work allows expanding application areas of Blender software and its addons as convenient and efficient tools of scientific visualization.

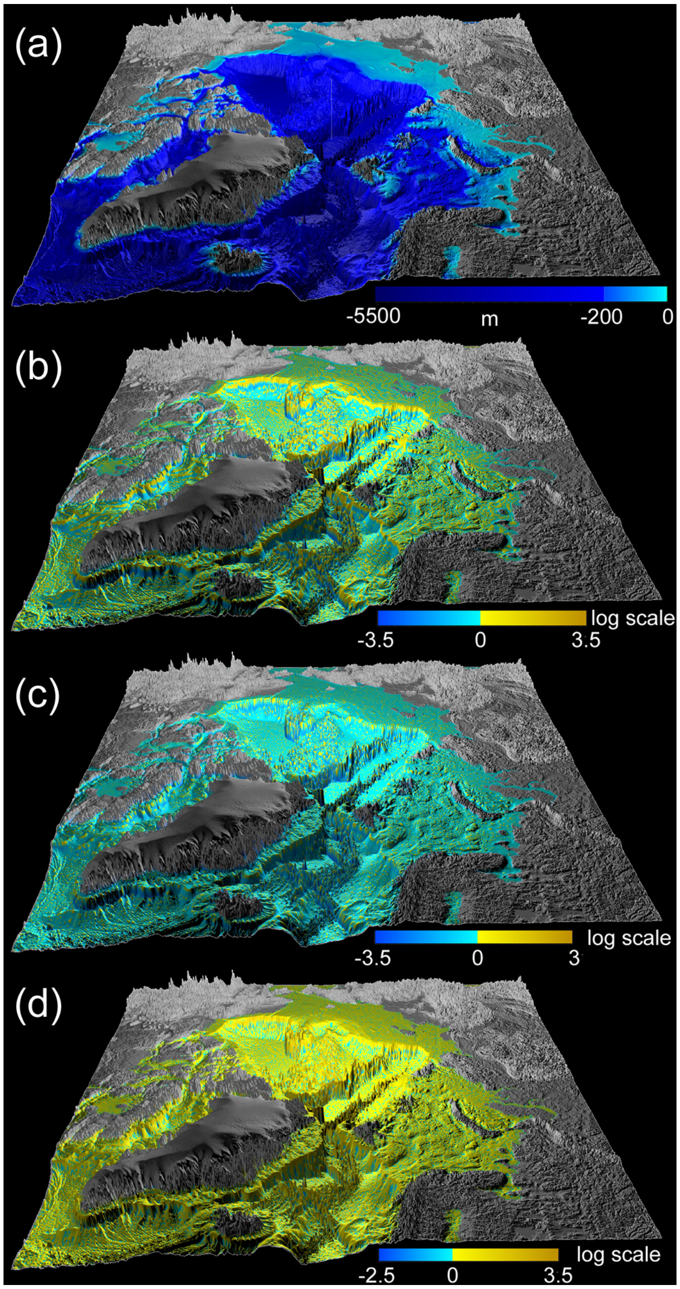

Figure 3. Examples of 5 km-gridded, 3D desktop models of the Arctic Ocean floor: (a) Depth. (b) Vertical curvature. (c) Minimal curvature. (d) Maximal curvature. Perspective views from the Atlantic [5].

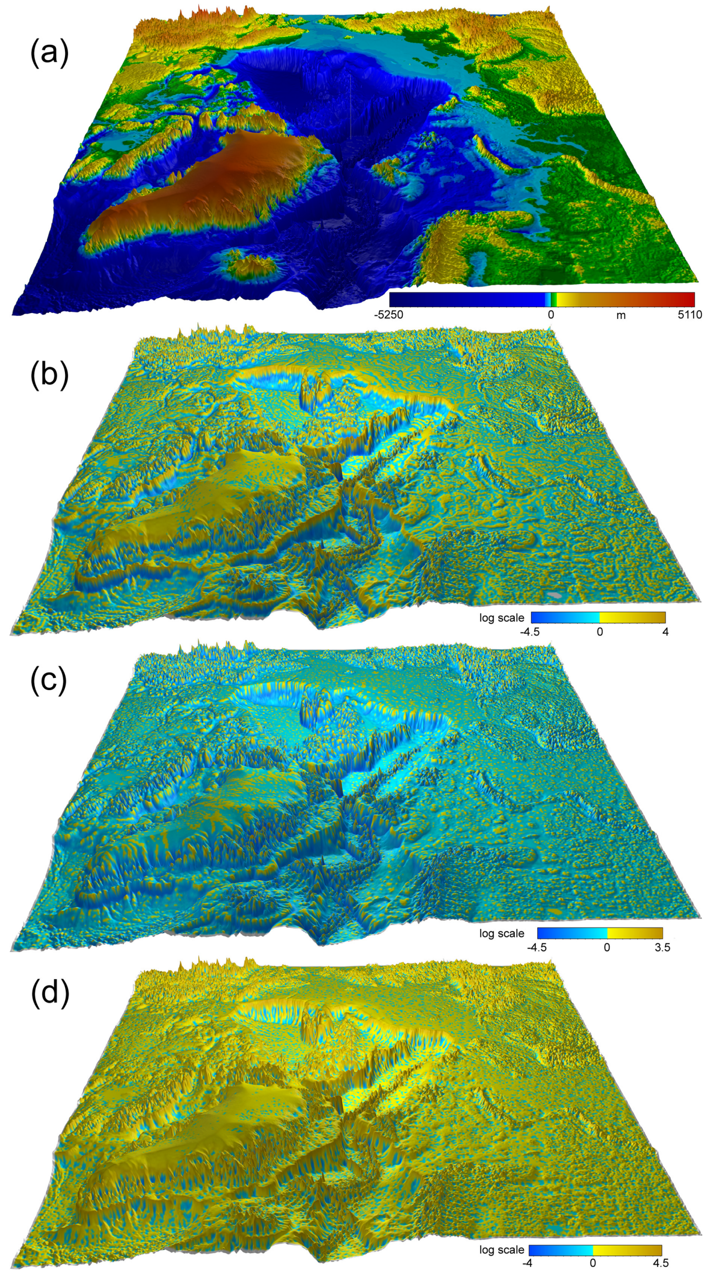

Figure 4. Examples of 10 km-gridded, 3D desktop models for the Arctic Ocean floor and adjacent territories: (a) Elevation/Depth. (b) Vertical curvature. (c) Minimal curvature. (d) Maximal curvature. Perspective views from the Atlantic [3].

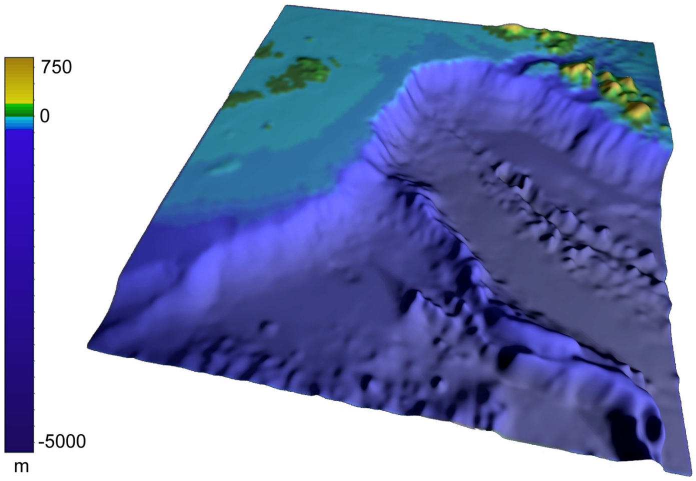

Figure 5. An example of 15 km-gridded, 3D desktop model for a portion of the Arctic Ocean floor (the Lomonosov Ridge): Elevation/Depth [10].

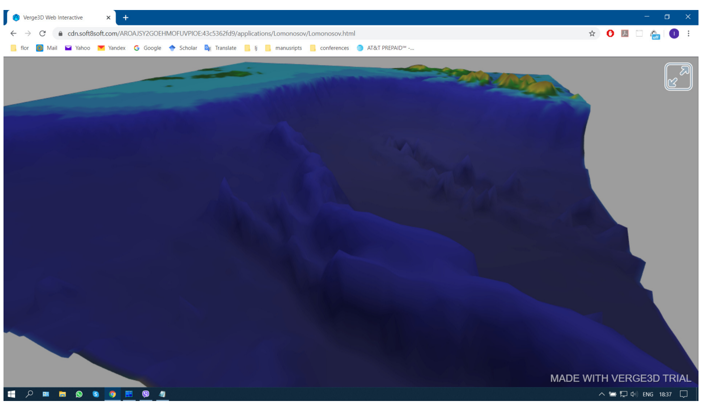

Figure 6. An example of a test, 15 km-gridded, 3D online model for a portion of the Arctic Ocean floor (the Lomonosov Ridge) presented within the Verge3D environment [6].

IV. CONCLUSIONS

We are now in the final phase of the project to develop the system for 3D geomorphometric modeling of the Arctic Ocean floor. Our experiments and results testify that the applied approach to the system development is flexible, effective, and functional. One of its advantages is that it is based on free and open-source software.

A final version of the system will provide:

- Storage of models for 18 morphometric variables derived from the IBCAO DEM.
- Interactive, real-time, 3D multiscale visualization of these morphometric models.
- Free access to this information via Internet.

V. ACKNOWLEDGMENTS

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