Development of a system for modelling the Arctic Ocean floor topography

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Objectives (2018 – 2020)

To develop a system for geomorphometric modelling of the topography of the Arctic Ocean floor.

The system will provide:

- Storage of a big digital elevation model (DEM) of the ocean floor
- Derivation of models of morphometric variables from the DEM
- Interactive 3D multiscale visualization of the obtained models
- Free access to this information via Internet

Morphometric variables

Elevation

Local variables

- Slope gradient
- Aspect
- Horizontal curvature
- Vertical curvature
- Mean curvature
- Gaussian curvature
- Minimal curvature
- Maximal curvature
- …..

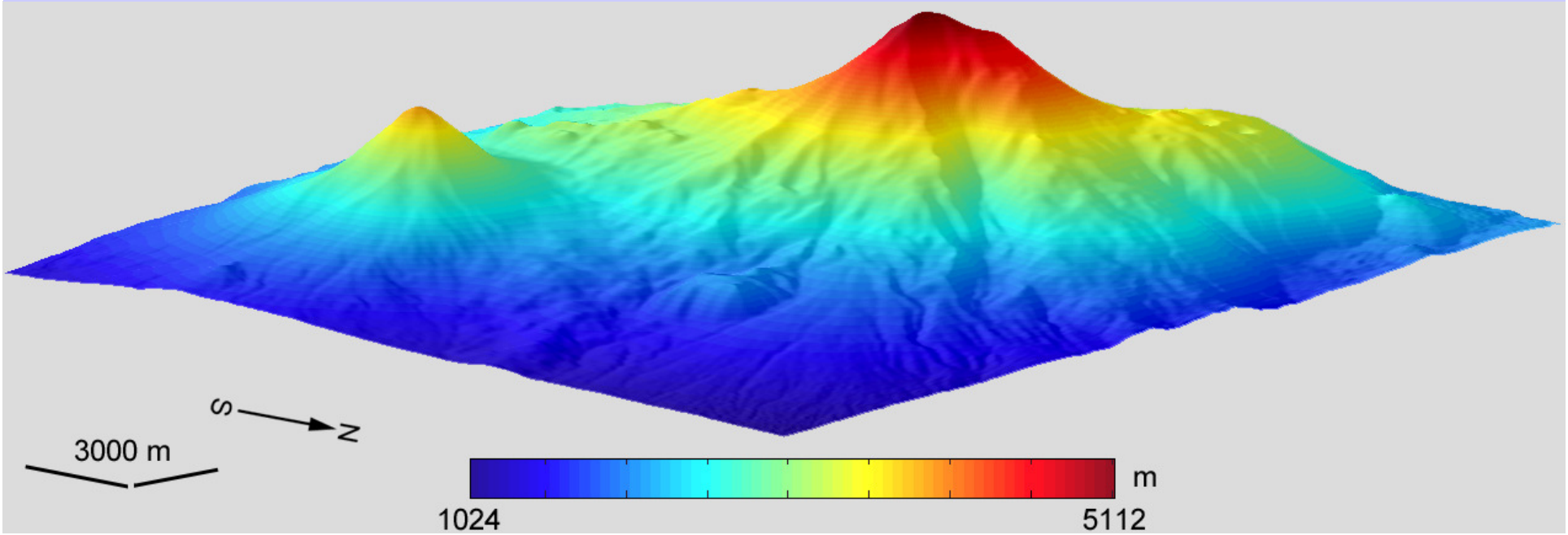
Nonlocal variables

- Catchment area
- Dispersive area
- ….

Combined variables

- Topographic index
- Stream power index
- ….

Elevation – initial data for morphometric calculations



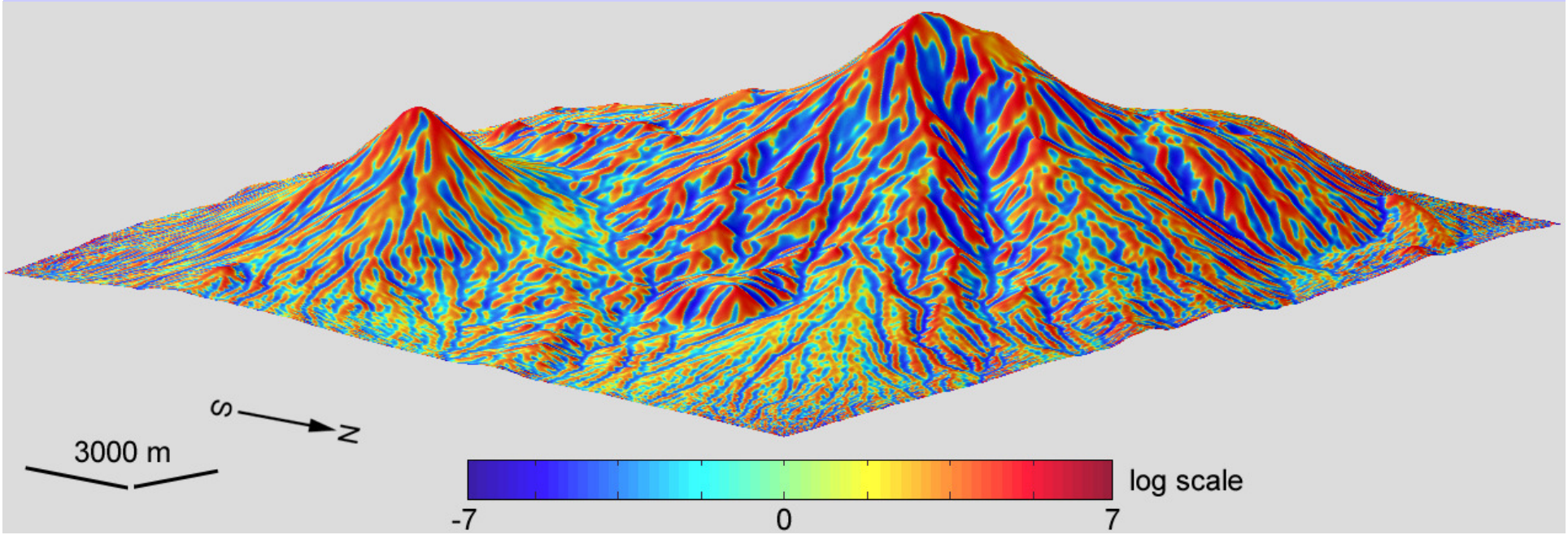
Mount Ararat
SRTM1
779 401 points (the matrix 1081 × 721), $w = 1''$

$$p = \frac{\partial z}{\partial x} \qquad q = \frac{\partial z}{\partial y}$$

Universal spectral analytical method for terrain modeling.

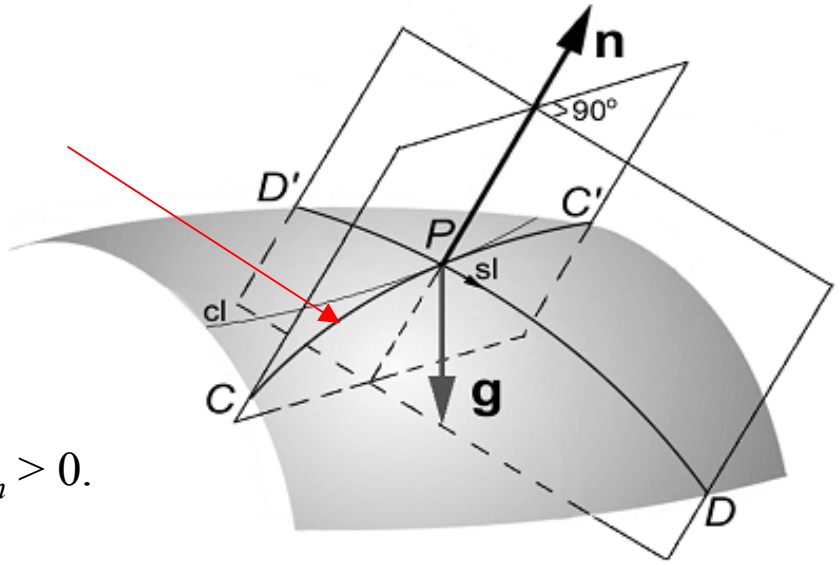
$$r = \frac{\partial^2 z}{\partial x^2} \qquad s = \frac{\partial^2 z}{\partial x \partial y} \qquad t = \frac{\partial^2 z}{\partial y^2}$$

Horizontal curvature



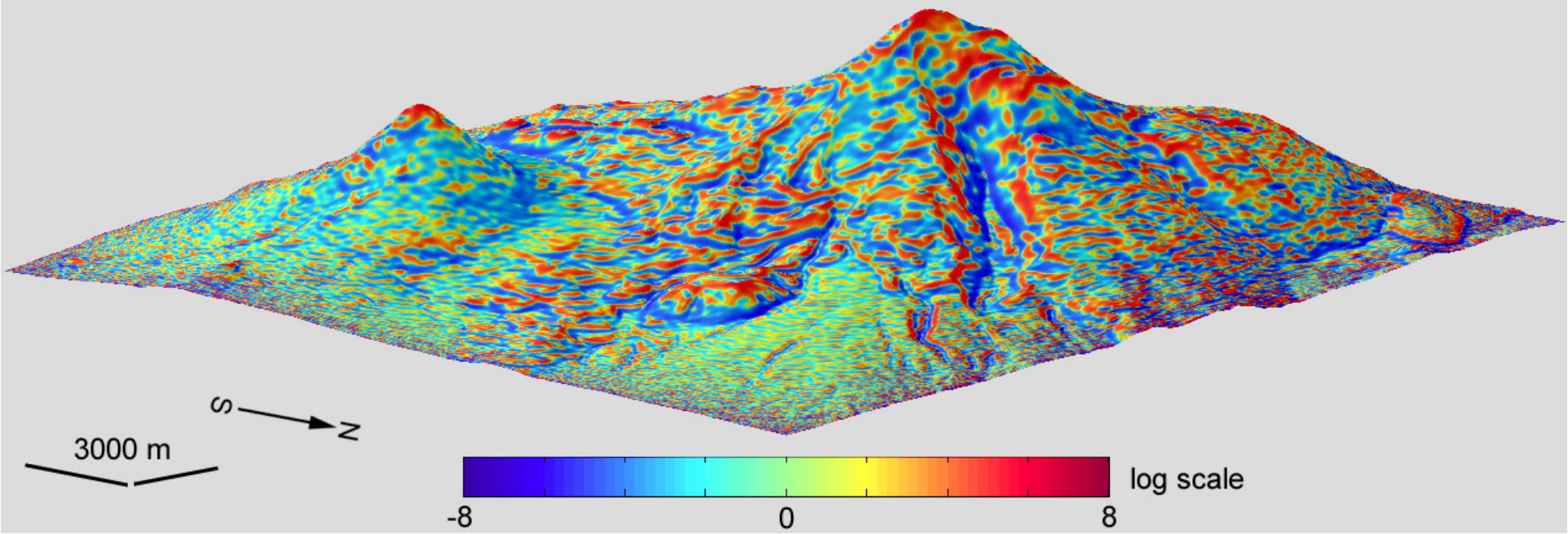
$$k_h = -\frac{q^2 r - 2pqs + p^2 t}{\left(p^2 + q^2\right)\sqrt{1 + p^2 + q^2}}$$

Horizontal curvature is a curvature of a normal section tangential to a contour line at a given point of the topographic surface.



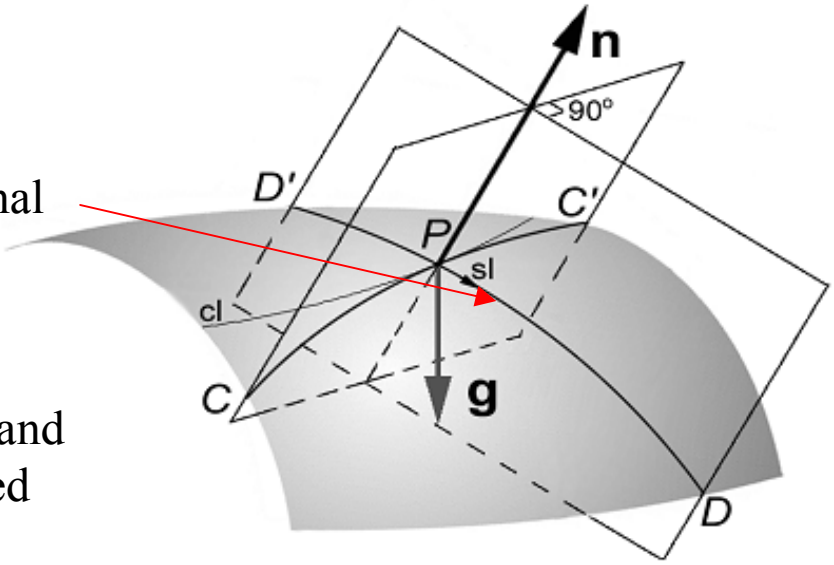
Horizontal curvature is a measure of flow convergence: gravity-driven overland and intrasoil lateral flows are converged where $k_h < 0$, and they are diverged where $k_h > 0$.

Vertical curvature



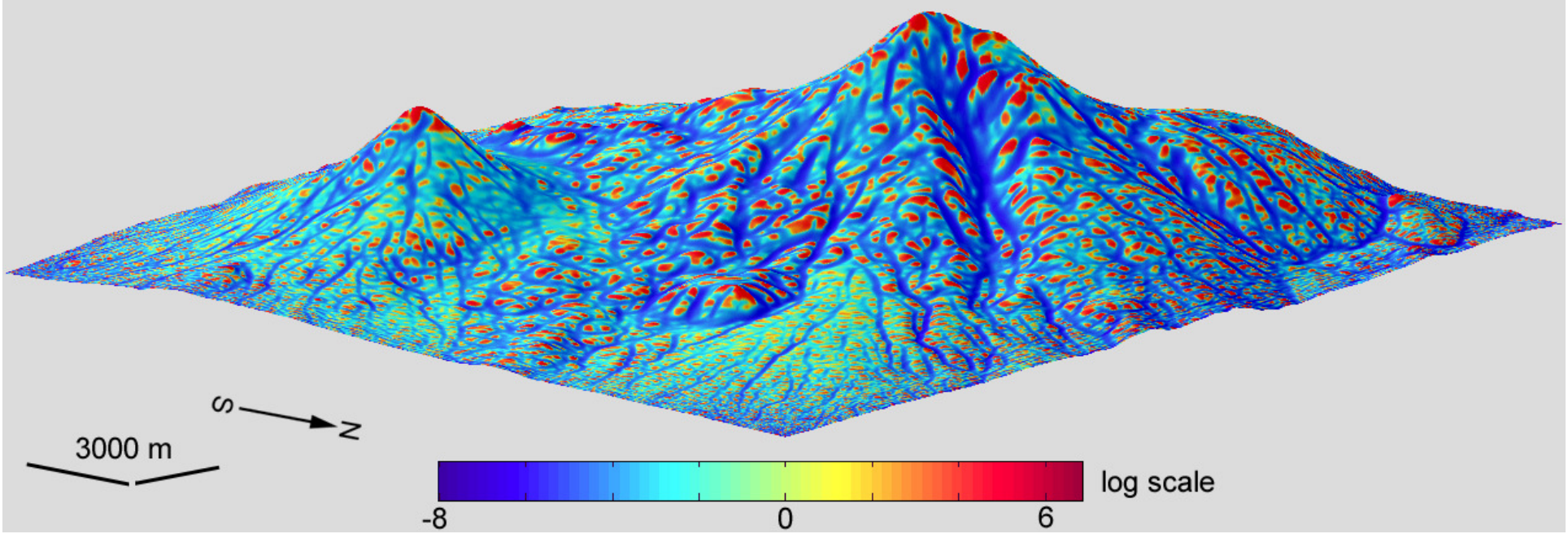
$$k_v = -\frac{p^2 r + 2pqs + q^2 t}{\left(p^2 + q^2\right)\sqrt{\left(1 + p^2 + q^2\right)^3}}$$

Vertical (or profile) curvature is the curvature of a normal section *DD'* having a common tangent line with a slope line *sl* at a given point *P* of the topographic surface.



Vertical curvature is a measure of relative deceleration and acceleration of gravity-driven flows: they are decelerated where $k_v < 0$; they are accelerated where $k_v > 0$.

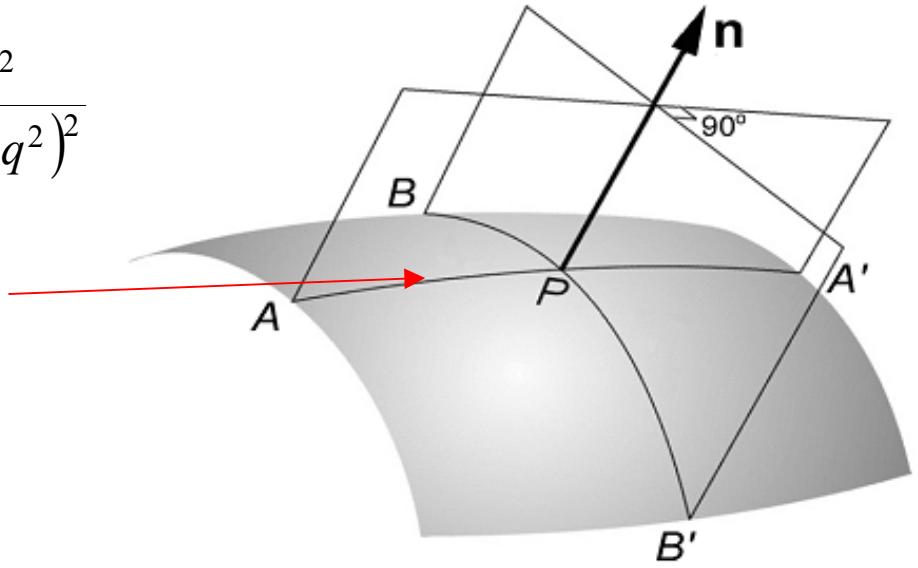
Minimal curvature



$$k_{\min} = H - \sqrt{H^2 - K}$$

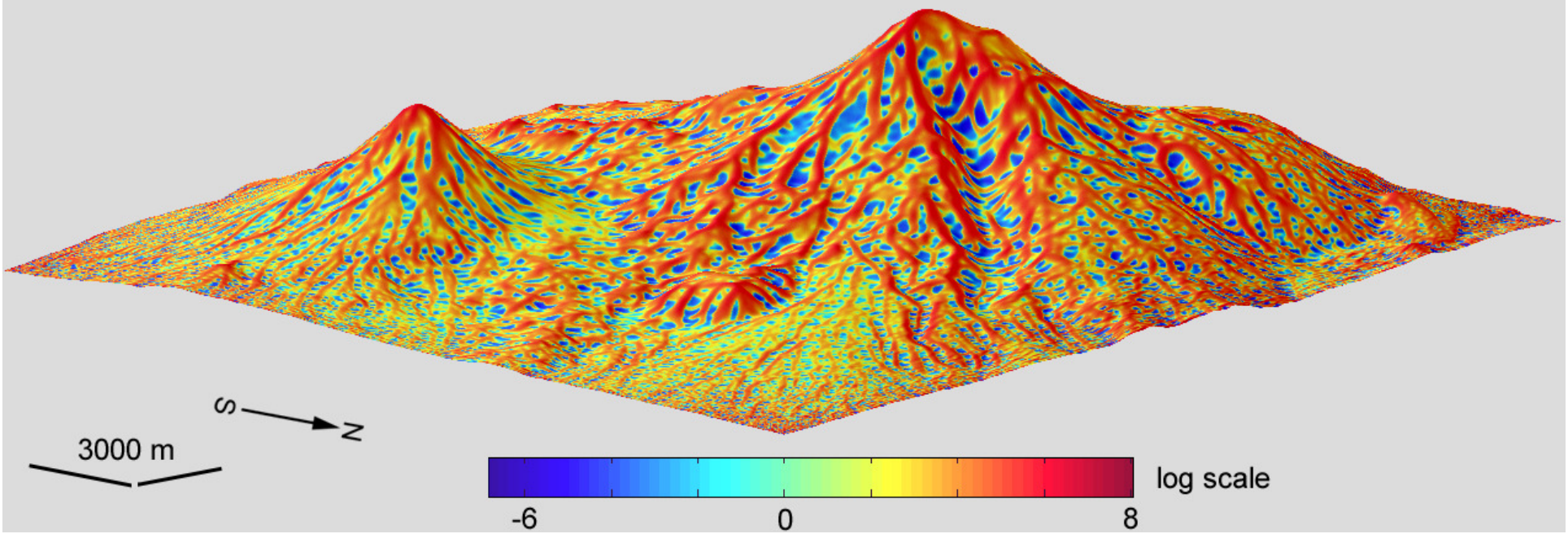
$$H = -\frac{(1+q^2)r - 2pqs + (1+p^2)t}{2\sqrt{(1+p^2+q^2)^3}} \qquad K = \frac{rt - s^2}{(1+p^2+q^2)^2}$$

Minimal curvature is a curvature of a principal section with the lowest value of curvature at a given point of the topographic surface



$k_{min} > 0$ corresponds to local convex landforms;
$k_{min} < 0$ relates to valleys.

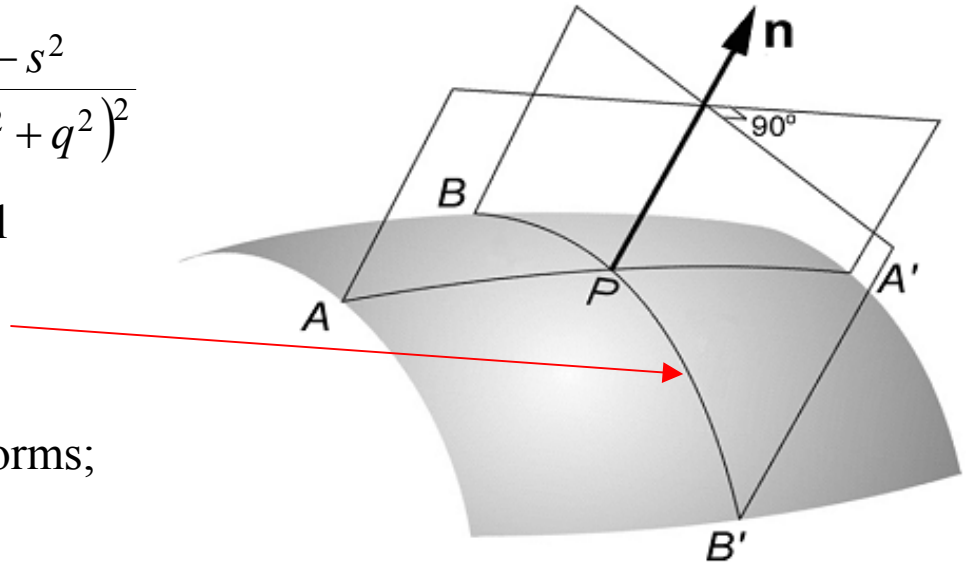
Maximal curvature



$$k_{\max} = H + \sqrt{H^2 - K}$$

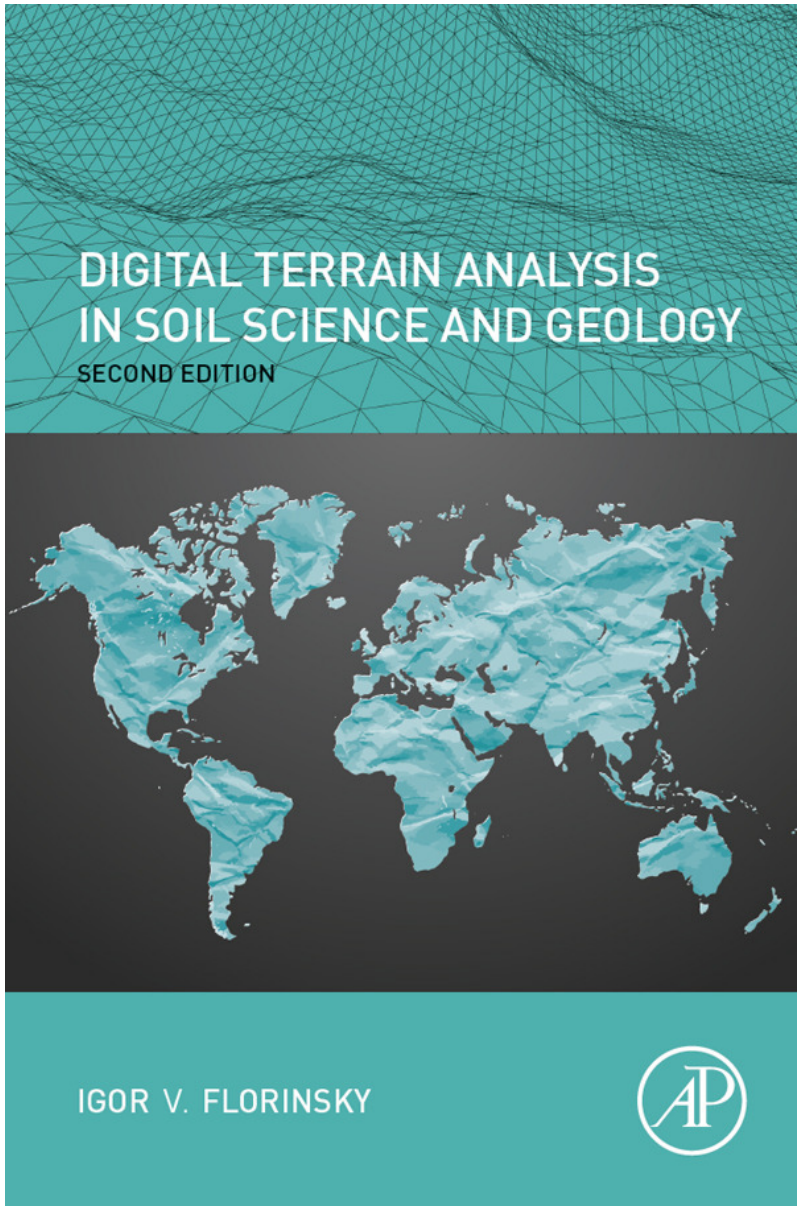
$$H = -\frac{(1+q^2)r - 2pqs + (1+p^2)t}{2\sqrt{(1+p^2+q^2)^3}} \qquad K = \frac{rt - s^2}{(1+p^2+q^2)^2}$$

Maximal curvature is a curvature of a principal section *BB*' with the highest value of curvature at a given point *P* of the surface.



$k_{max} > 0$ correspond to elongated convex landforms;
$k_{max} < 0$ relate to local concave landforms.

Reference



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Amsterdam, 486 p.

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Initial data

International Bathymetric Chart of the Arctic Ocean (IBCAO), version 3.0

Resolution: 500 m ~ 135 million points

Testing DEM 1:

Resolution: 5 km

1,347,921 points (1161 × 1161 matrix)

Testing DEM 2:

Resolution: 10 km

337,561 points (581 × 581 matrix)

IBCAO, 2012. *IBCAO Version 3.0*. The International Bathymetric Chart of the Arctic Ocean, http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/ibcaoversion3.html

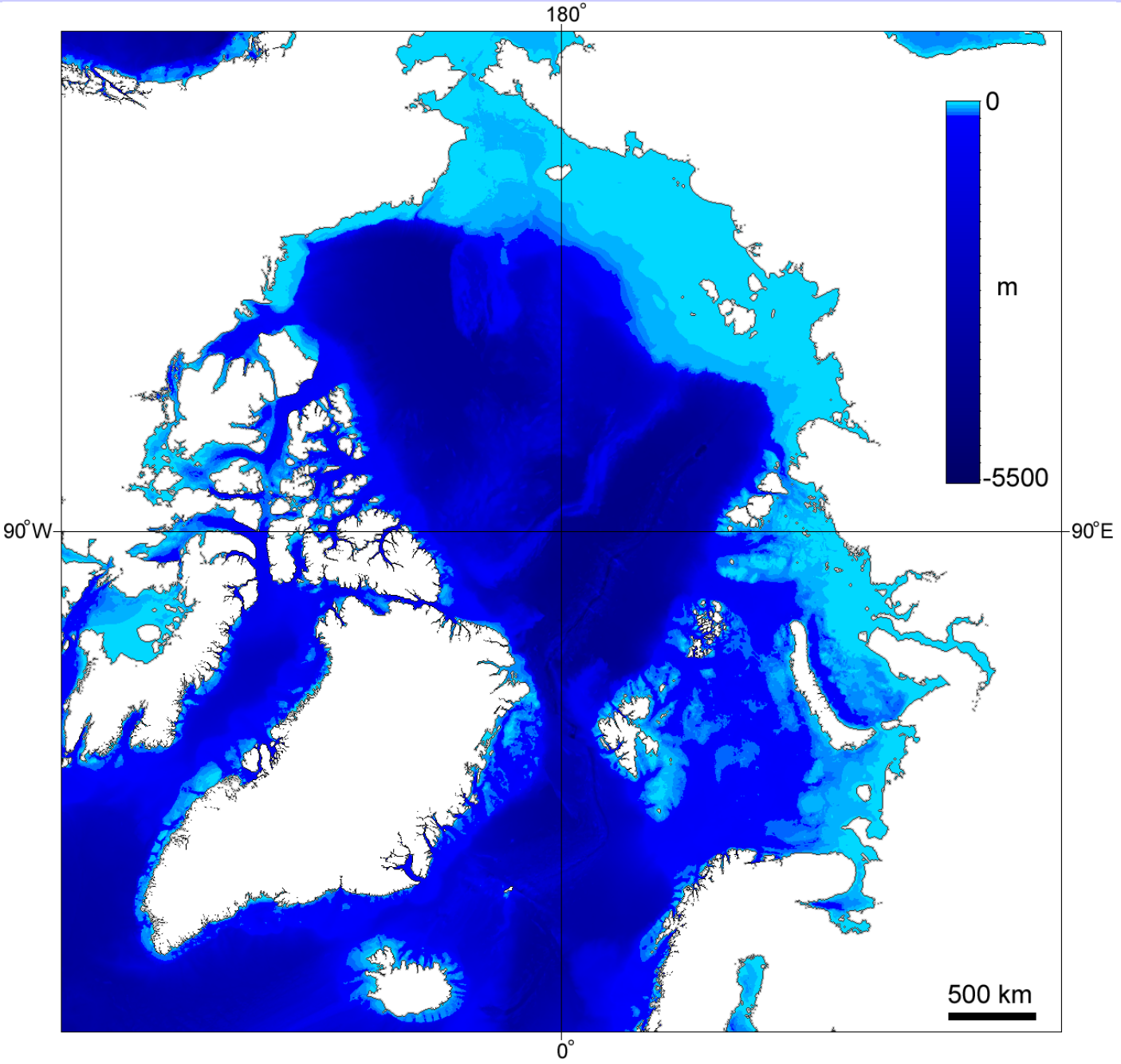
Jakobsson, M., et al. 2012. The International Bathymetric Chart of the Arctic Ocean (IBCAO) Version 3.0. *Geophysical Research Letters* 39: L12609.

Software

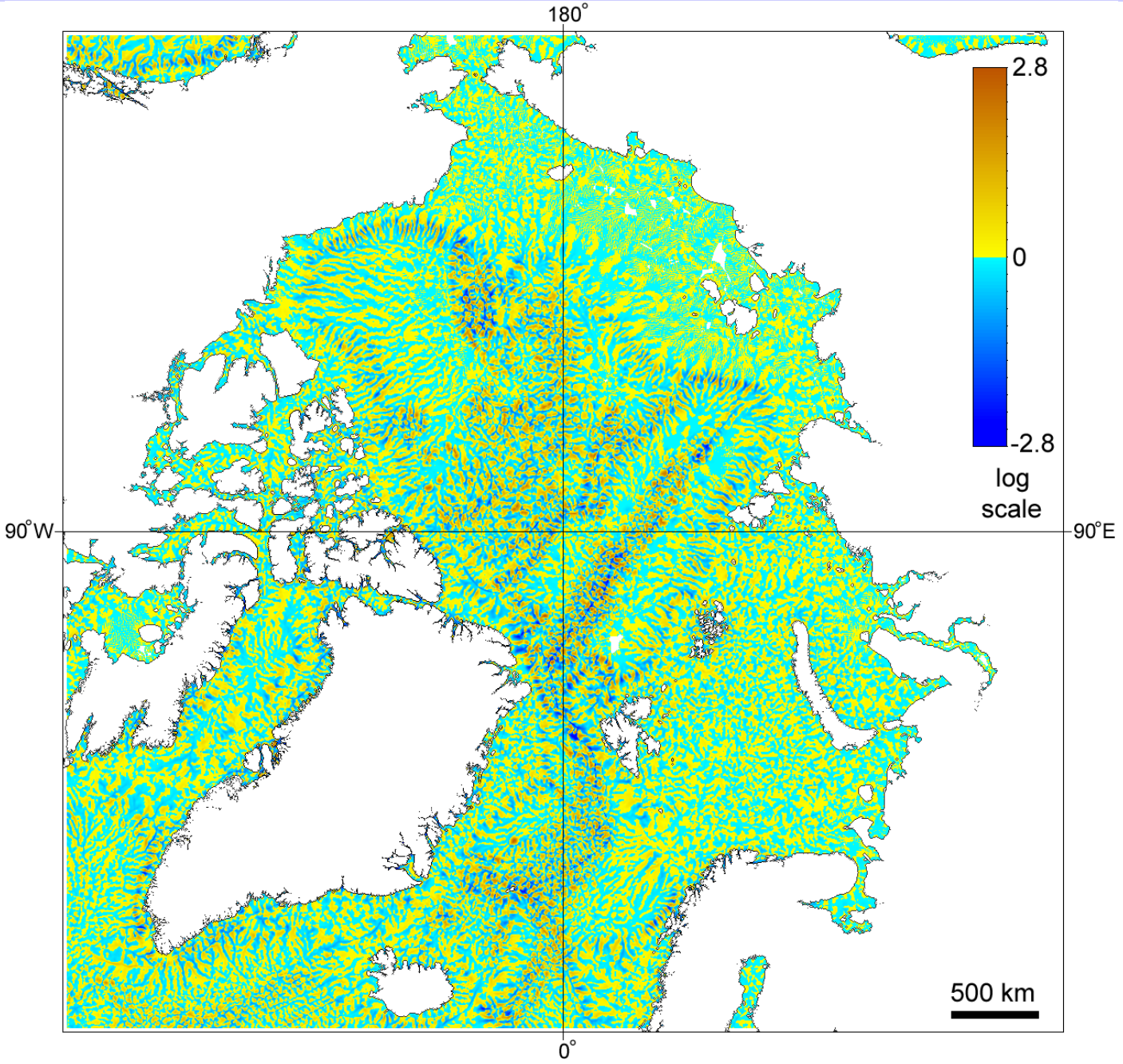
- Morphometric calculations:
  software LandLord (Florinsky, 2012).

- 3D online vizualization:
  free open-source Blender package
  (https://www.blender.org).

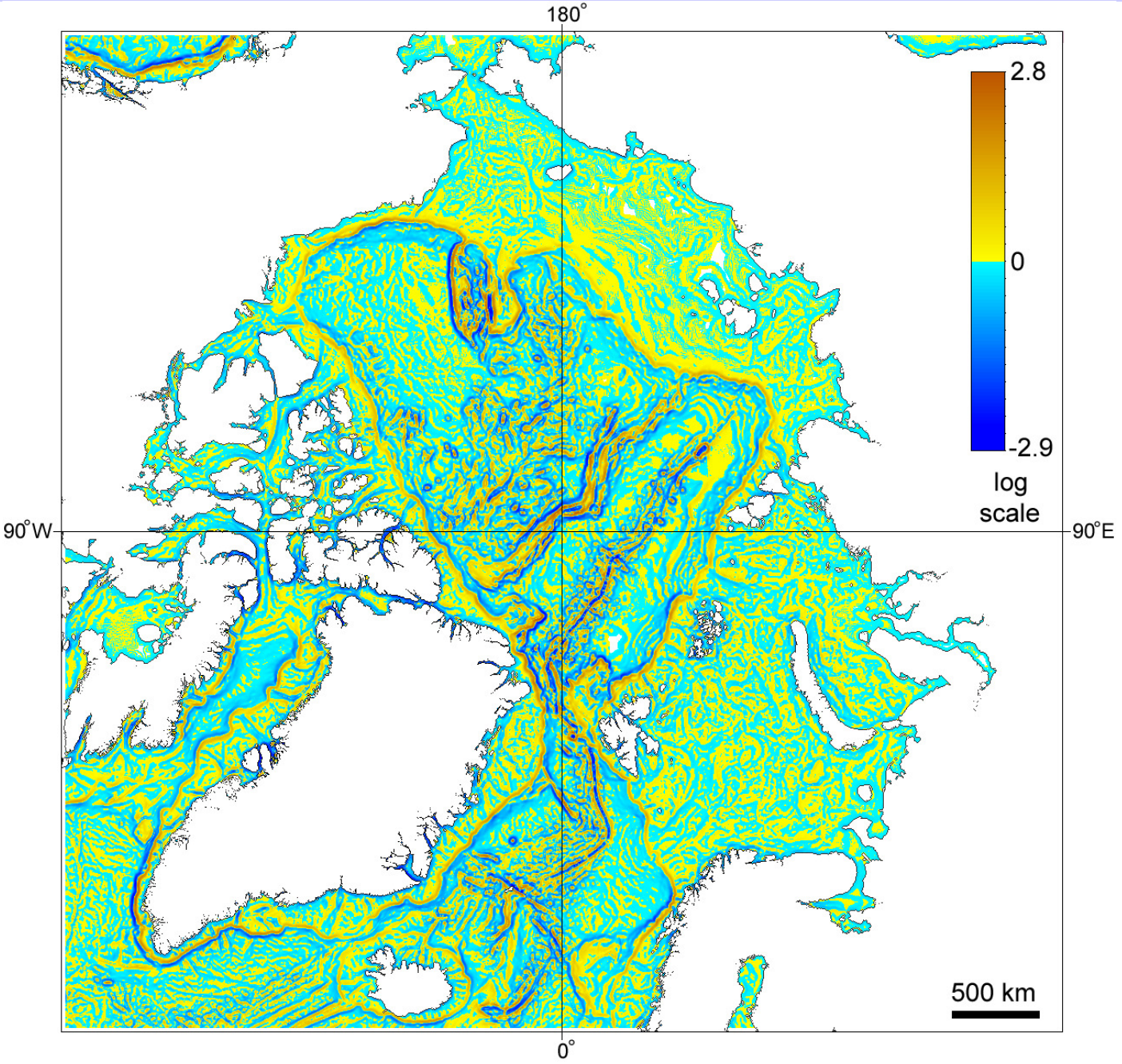
The Arctic Ocean floor: elevations [Testing DEM 1]



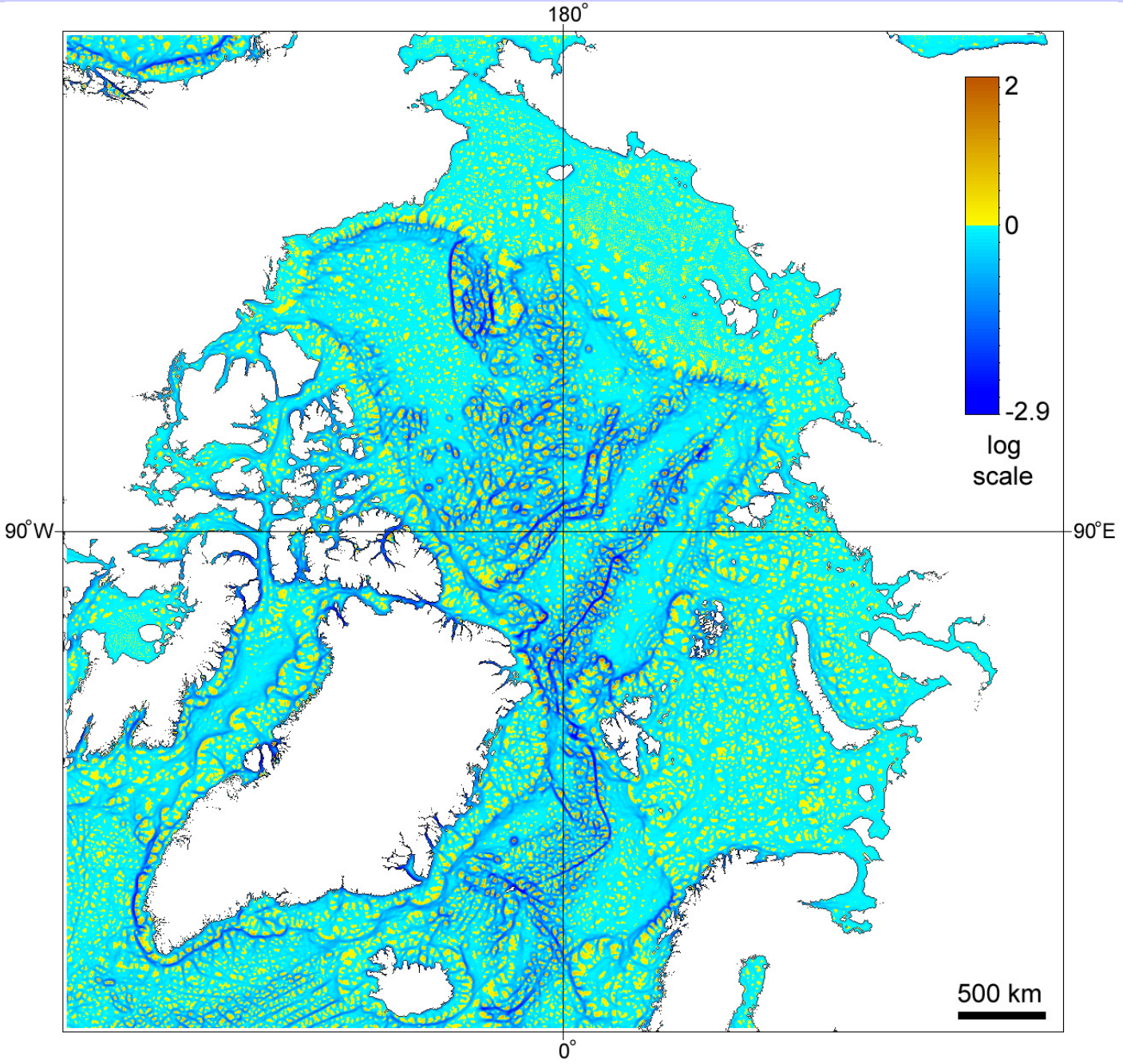
The Arctic Ocean floor: horizontal curvature [Testing DEM 1]



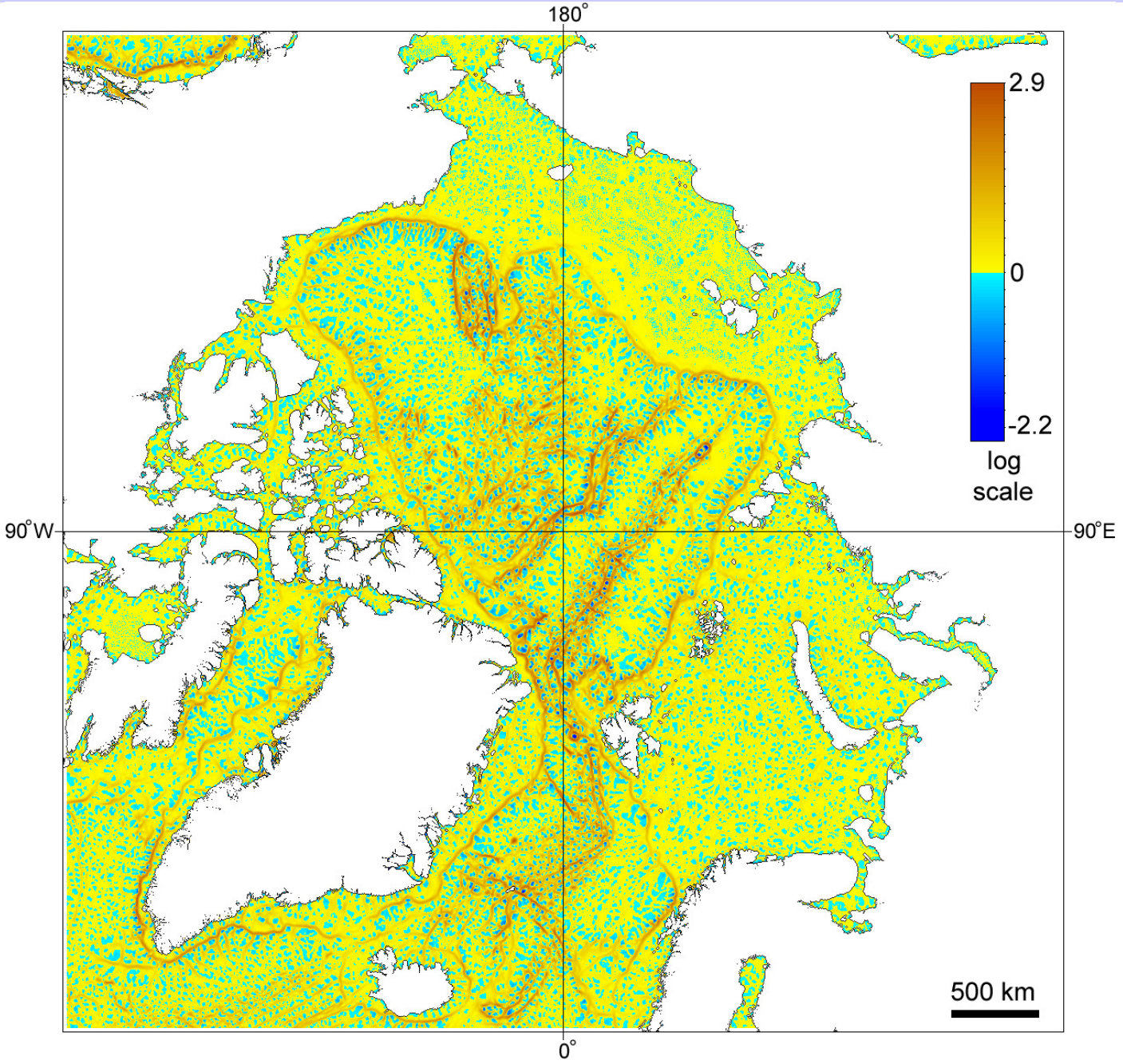
The Arctic Ocean floor: vertical curvature [Testing DEM 1]



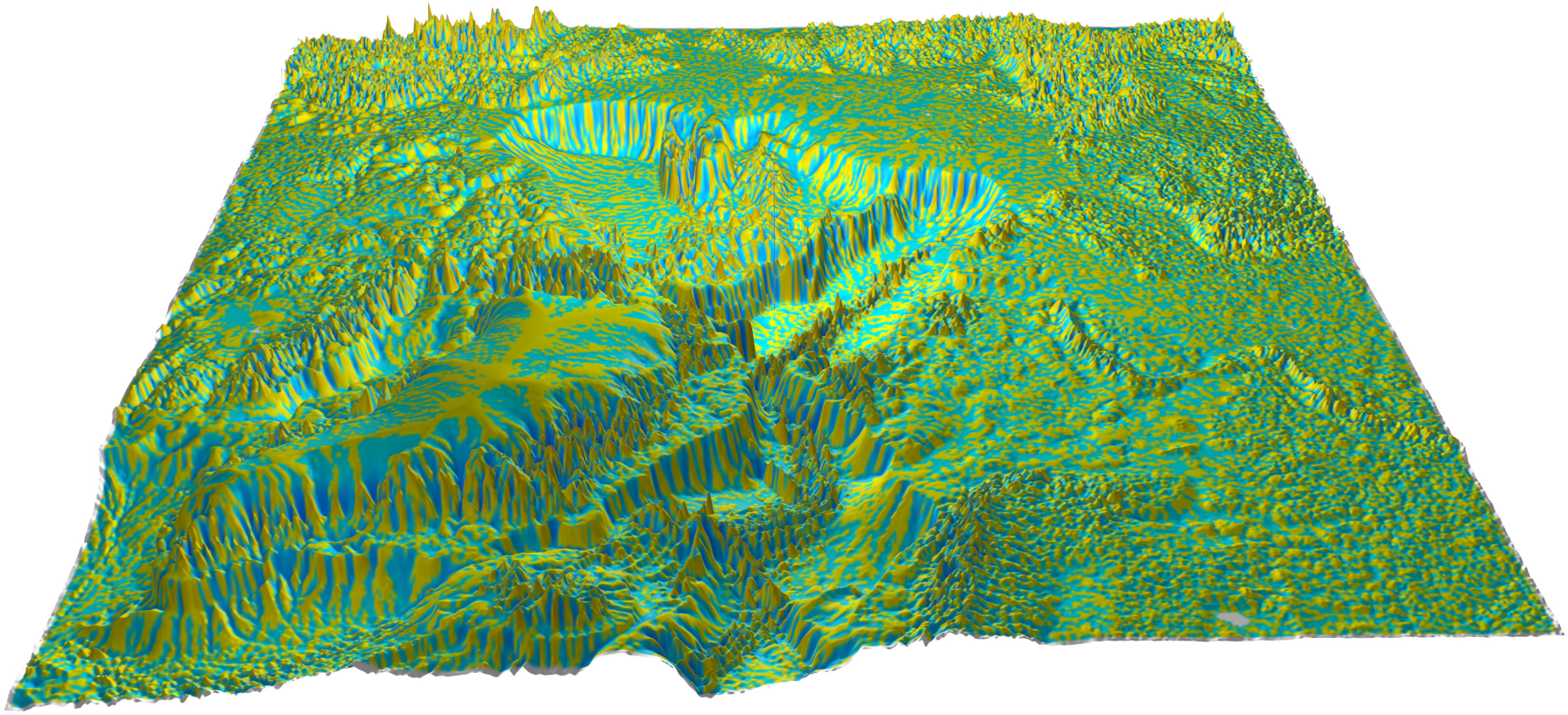
The Arctic Ocean floor: minimal curvature [Testing DEM 1]



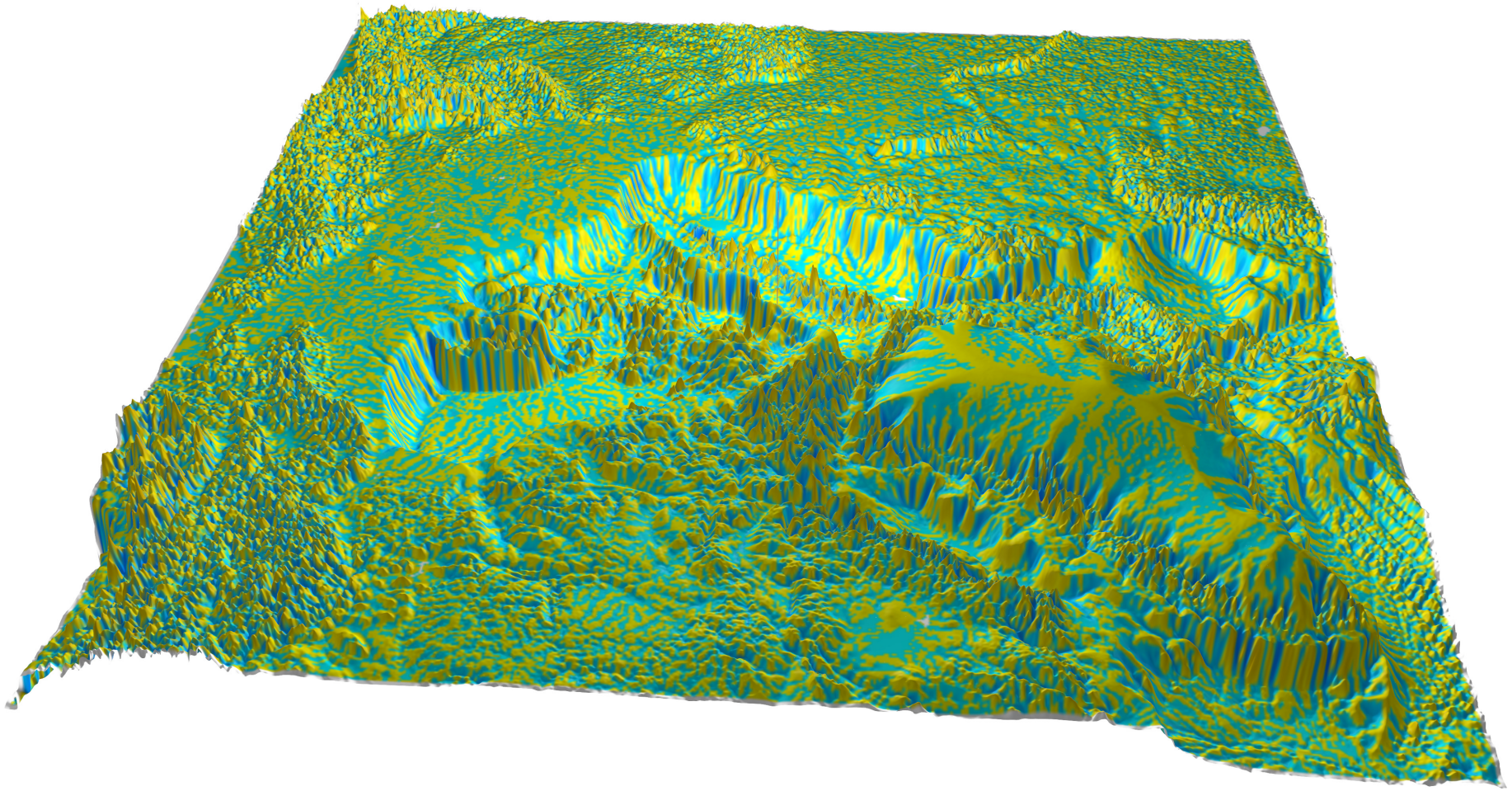
The Arctic Ocean floor: maximal curvature [Testing DEM 1]



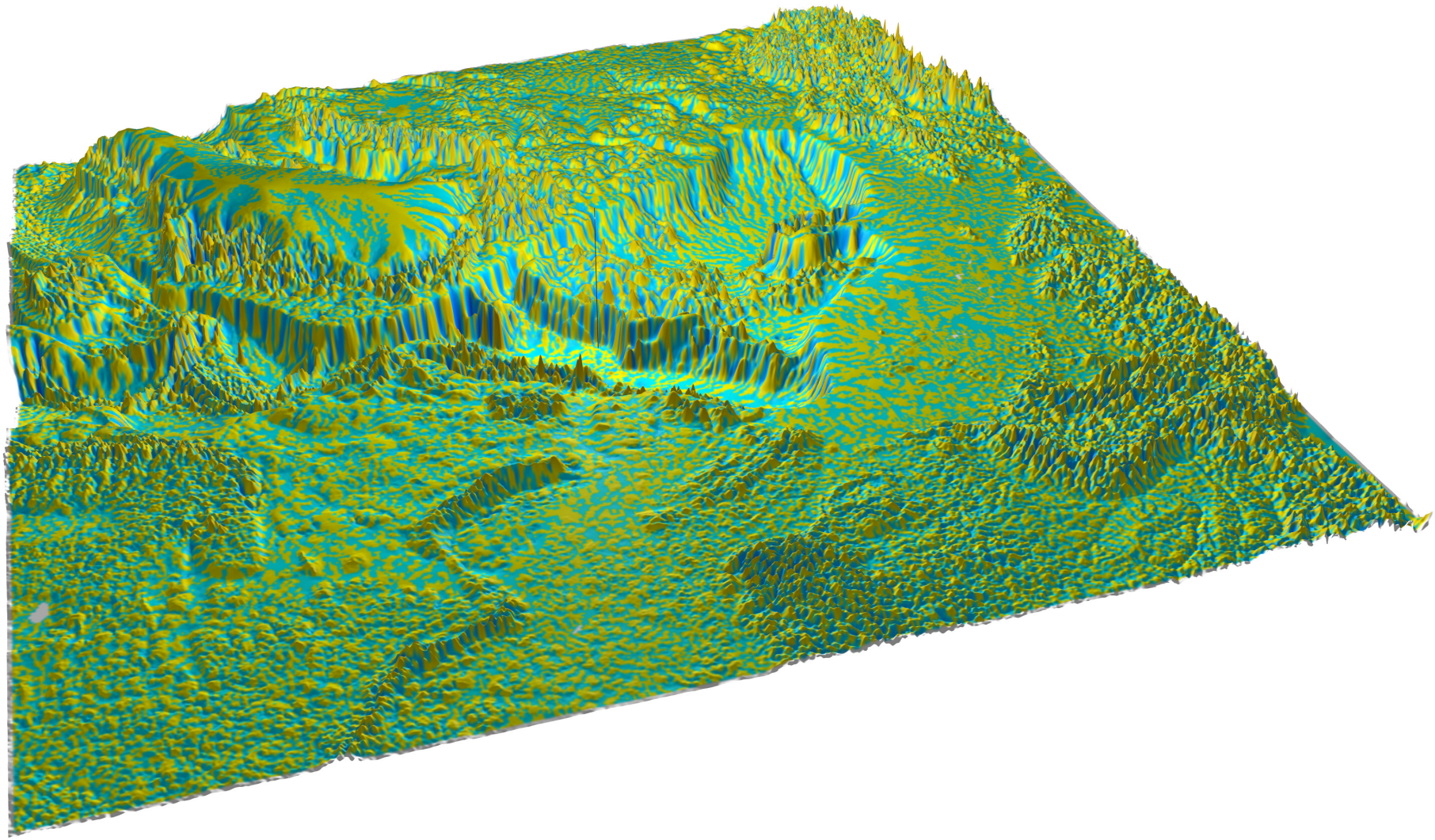
3D morphometric models (horizontal curvature) [Testing DEM 2]



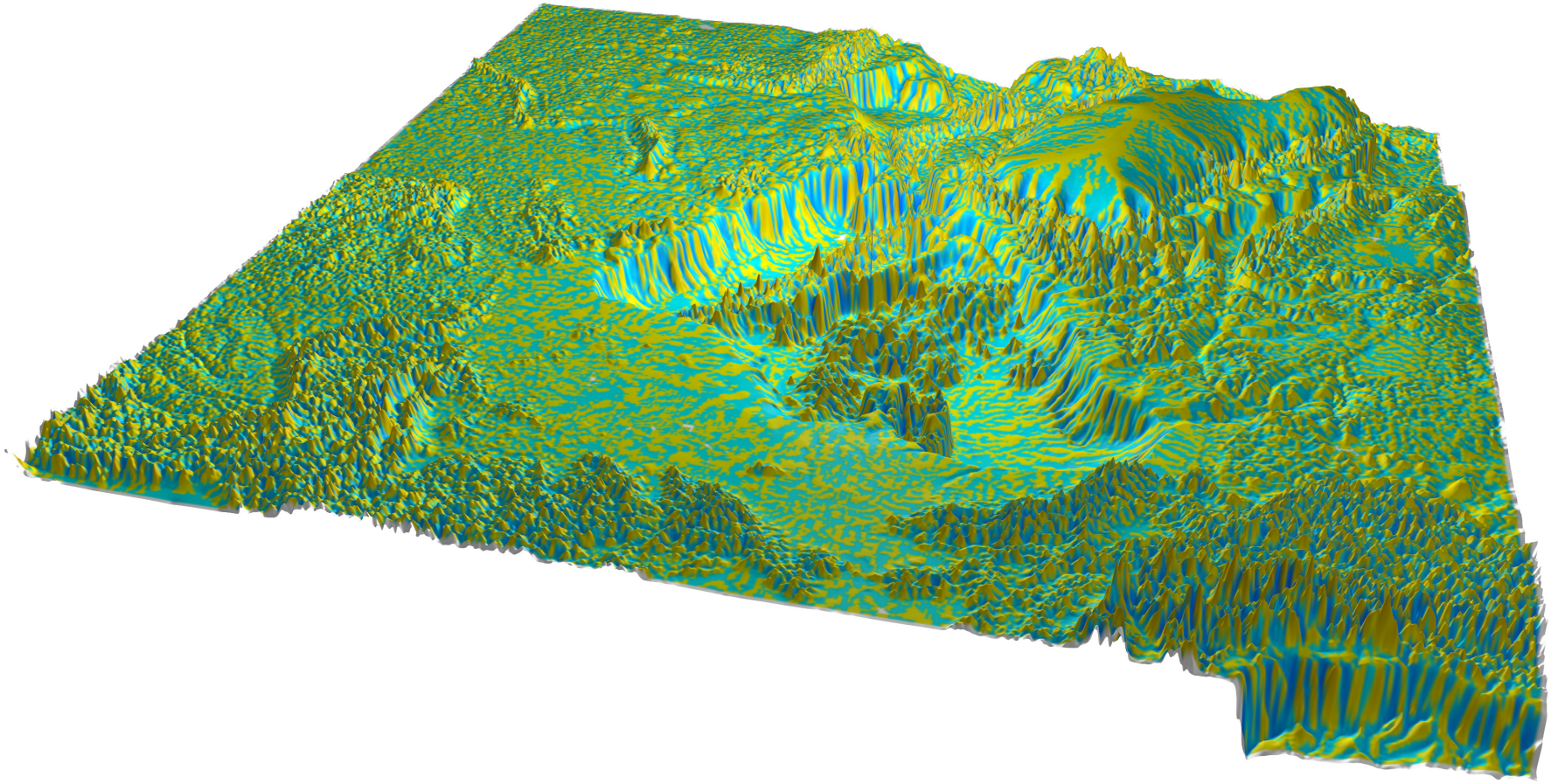
3D morphometric models (horizontal curvature) [Testing DEM 2]



3D morphometric models (horizontal curvature) [Testing DEM 2]



3D morphometric models (horizontal curvature) [Testing DEM 2]



Conclusions

As a result of the project, we will develop an information and computing system for morphometric modelling of the Arctic Ocean floor.

The system will provide storage of a big DEM for the ocean floor; derivation of morphometric models from the DEM; interactive 3D multiscale visualization of the obtained models; and free access to this information via the Internet, with the possibility of 3D real-time visualization online.

A new interactive online information tool will be created to support hydrographic, marine geomorphological, geological, geophysical, and oceanological studies of the Arctic Region.

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