Spline interpolation of sparse bathymetric data for digital elevation models (DEMs)

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Overview

Digital elevation models (DEMs) are the framework for modeling numerous oceanic processes including tsunami propagation and ocean circulation. The accuracy of modeling such oceanic processes is largely dependent on the accuracy of the DEM. Many regions of interest have sparse bathymetric data, which require data interpolation to create a continuous model of the seafloor. There are several different interpolation gridding algorithms such as spline, inverse distance weighting (IDW), and kriging. The National Geophysical Data Center (NGDC), an office of the National Oceanic and Atmospheric Administration (NOAA), in conjunction with the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado at Boulder, both quantitatively and qualitatively assessed the accuracy of modeling the seafloor using spline interpolation gridding algorithms from *MB-System 5.1.0* and *Generic Mapping Tools (GMT) 4.4.0* software packages.

Study Area

The region of the North Atlantic Ocean located from 72.25 W to 64.85 W and 37.55 N to 40.65 N was selected to evaluate the accuracy of various interpolation methods. The region is ideal because of the variety of morphologic regimes, including the continental shelf, continental slope, abyssal plain, submarine canyons, and the New England seamounts (**Figure 1**). Also, the region has dense multibeam bathymetry data coverage that represented the "true" elevation for comparison of the interpolated surfaces.

To develop the "true" elevation grid, NGDC used multibeam data referenced to the World Geodetic System of 1984 (WGS 84) from NOAA NGDC multibeam database. The data were cleaned to remove artifacts and eliminate superseded surveys, and gridded at 9 arc-seconds (approximately 270 m) referenced to the WGS 84 datum. The "true" elevation grid was then projected to UTM Zone 19 N at 500 m resolution. We obtained trackline data referenced to WGS 84 from the NGDC trackline database. The data were projected from WGS 84 to UTM Zone 19 N and elevation values from the "true" elevation grid were extracted at every trackline (easting, northing) position (**Figure 2**).

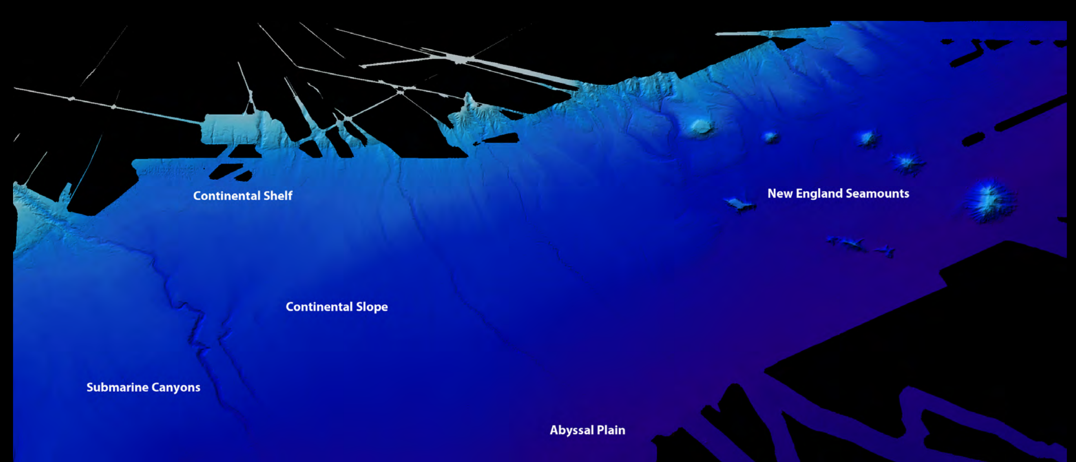

Figure 1. Hillshade of the "true" elevation grid derived from the NGDC multibeam databse. Labels denote morphologic regimes.

Methodology

NGDC evaluated the accuracy of spline interpolation using two different software packages, *MB-System* and *GMT*. The *MB-System* spline interpolation program "mbgrid" and the *GMT* program "surface" each have several parameters that affect the interpolated surface. For both programs, the most fundamental parameter is the tension value. Tension alters the thin plate spline algorithm, with a tension of zero corresponding to a minimum curvature surface with free edges. For "mbgrid," the tension value has a possible range of 0 to infinity. For "surface," the tension value has a possible range of 0 to 1. NGDC found the effects of the other parameters on the interpolated surface to be minimal relative to the effect of tension.

To analyze the *MB-System* and *GMT* interpolated surfaces, the trackline data with sampled elevations from the "true" elevation grid was gridded using various tension values. The sampled data were transformed from UTM Zone 19 N to WGS 84 to be gridded using "mbgrid" and "surface." The interpolation grid was projected to UTM zone 19 N with negligible distortion. The interpolated grid and "true" elevation grid were differenced to determine the accuracy of the interpolation method with various tension values.

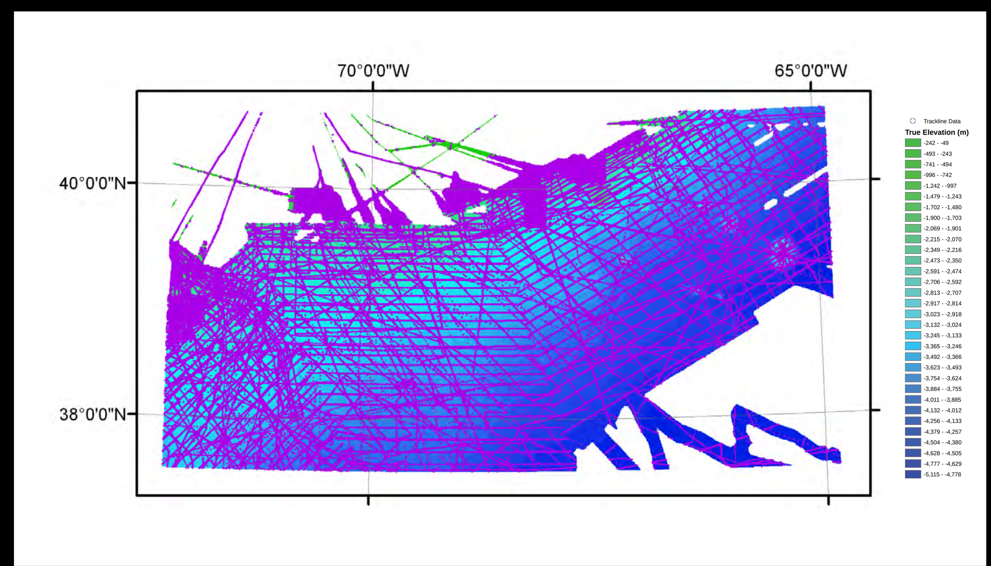

Figure 2. Location of the sparse trackline data with elevations sampled from the "true" elevation grid.

Results

The interpolated surfaces and difference grids revealed important characteristics of spline interpolation of sparse bathymetric data. As expected, spline interpolation best represents areas with low relief such as the continental shelf and abyssal plain. Spline interpolation cannot effectively represent high relief areas such as submarine canyons or seamounts where there are no data. For both software programs, interpolated surfaces with a low tension value resulted in the best-fit representation of the "true" elevation grid as a whole. Using "mbgrid" with a high tension value created spurious oscillations, including an artificial seamount (**Figures 3, 4**), but better characterized the linear nature of submarine canyons (**Figure 5**). For "mbgrid," a tension value of 1.25 resulted in a standard deviation between the interpolated surface and "true" elevation grid of 25.1 meters. For "surface," a tension value of 0.05 resulted in a standard deviation of 21.5 meters (**Figures 6, 7**).

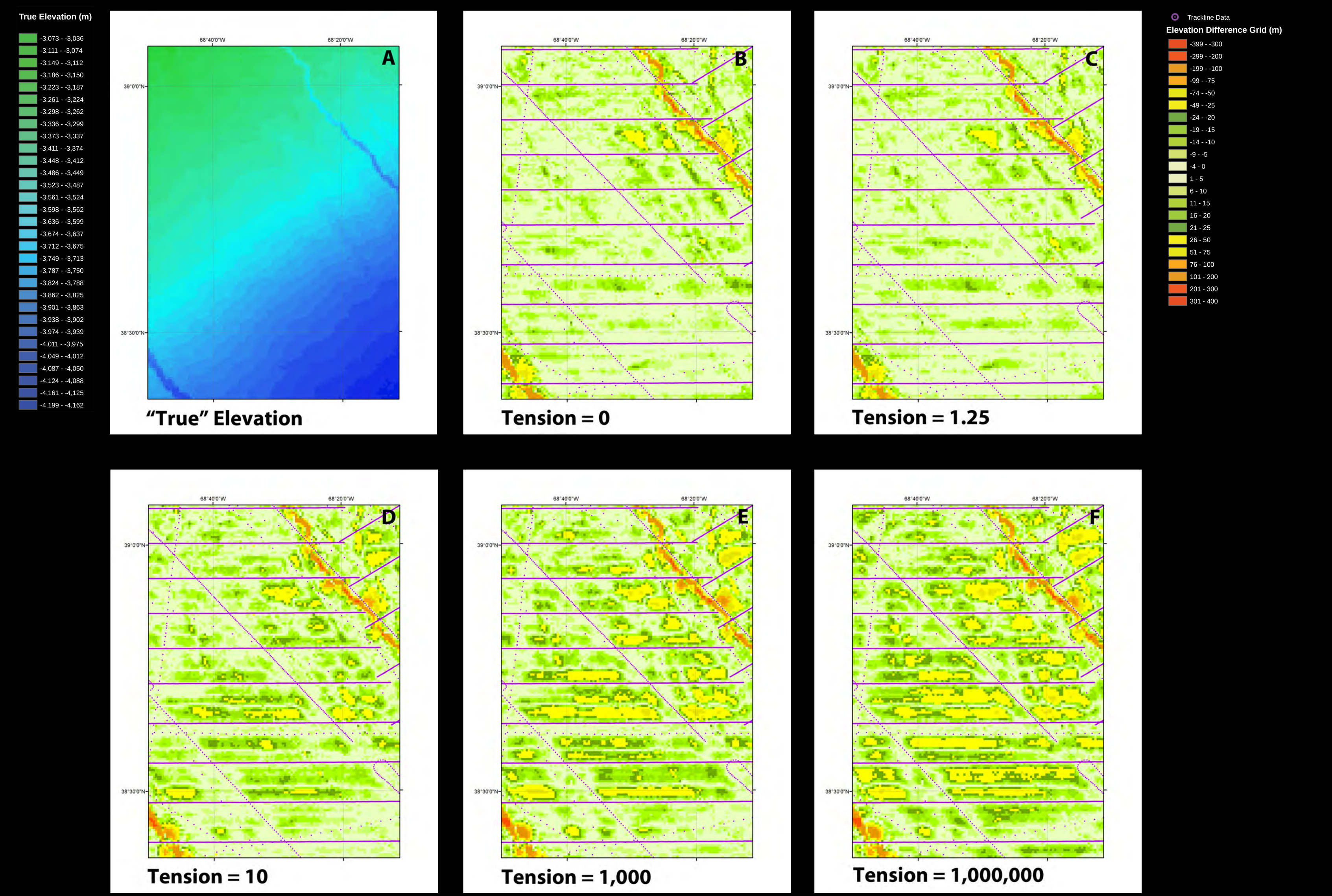

Figure 3. Spurious oscillations of interpolation between trackline data introduced by tension. Tile A is the "true" elevation grid. Tiles B - F represent the difference between spline interpolation with various tension values and the "true" elevation grid.

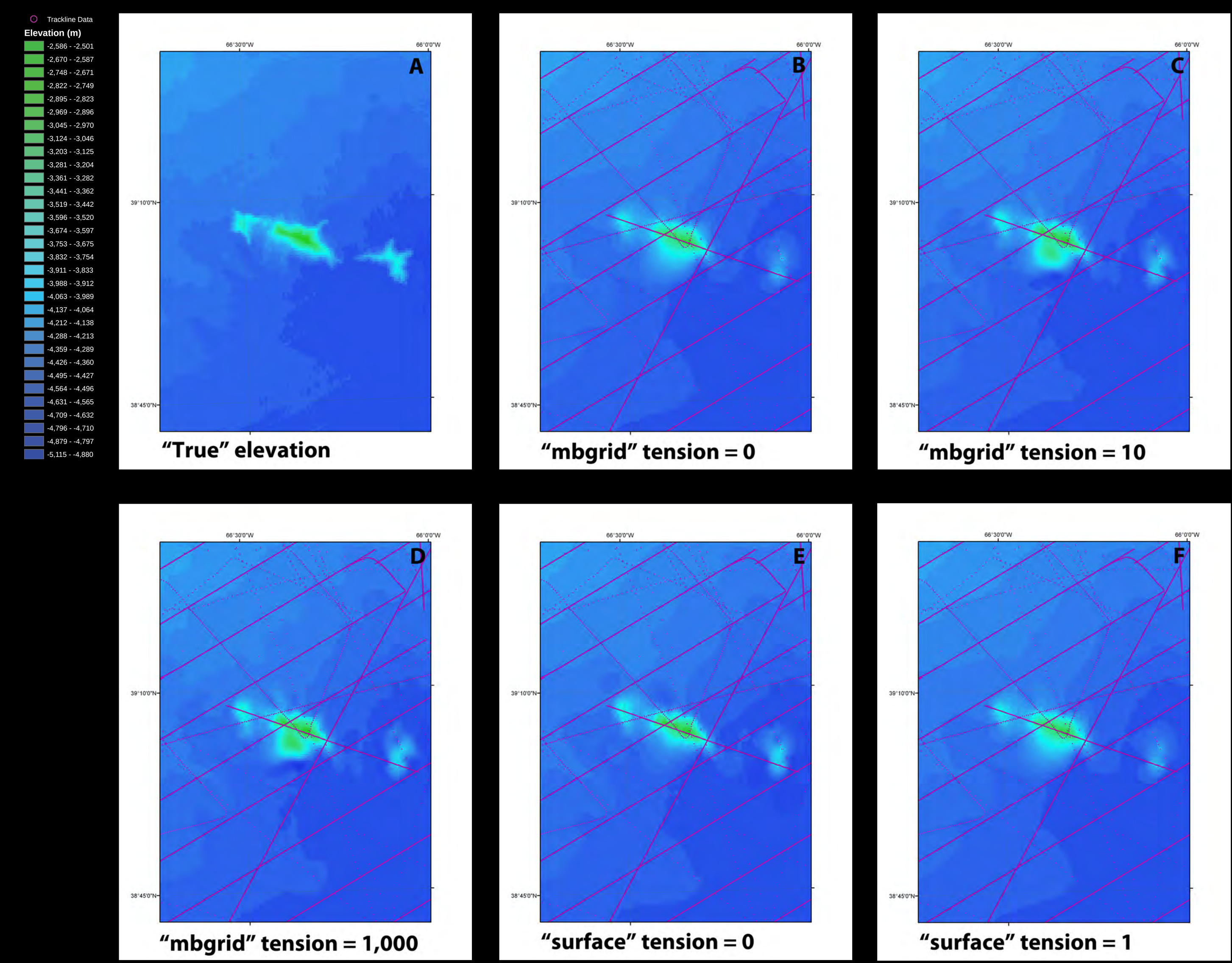

Figure 4. Representation of the Buell Seamount using different spline interpolation methods. Tile A is the "true" elevation grid. Tiles B - D illustrate an artificial seamount adjacent to the Buell Seamount resulting from spurious oscillations using "mbgrid." Tiles E and F show interpolation using "surface."

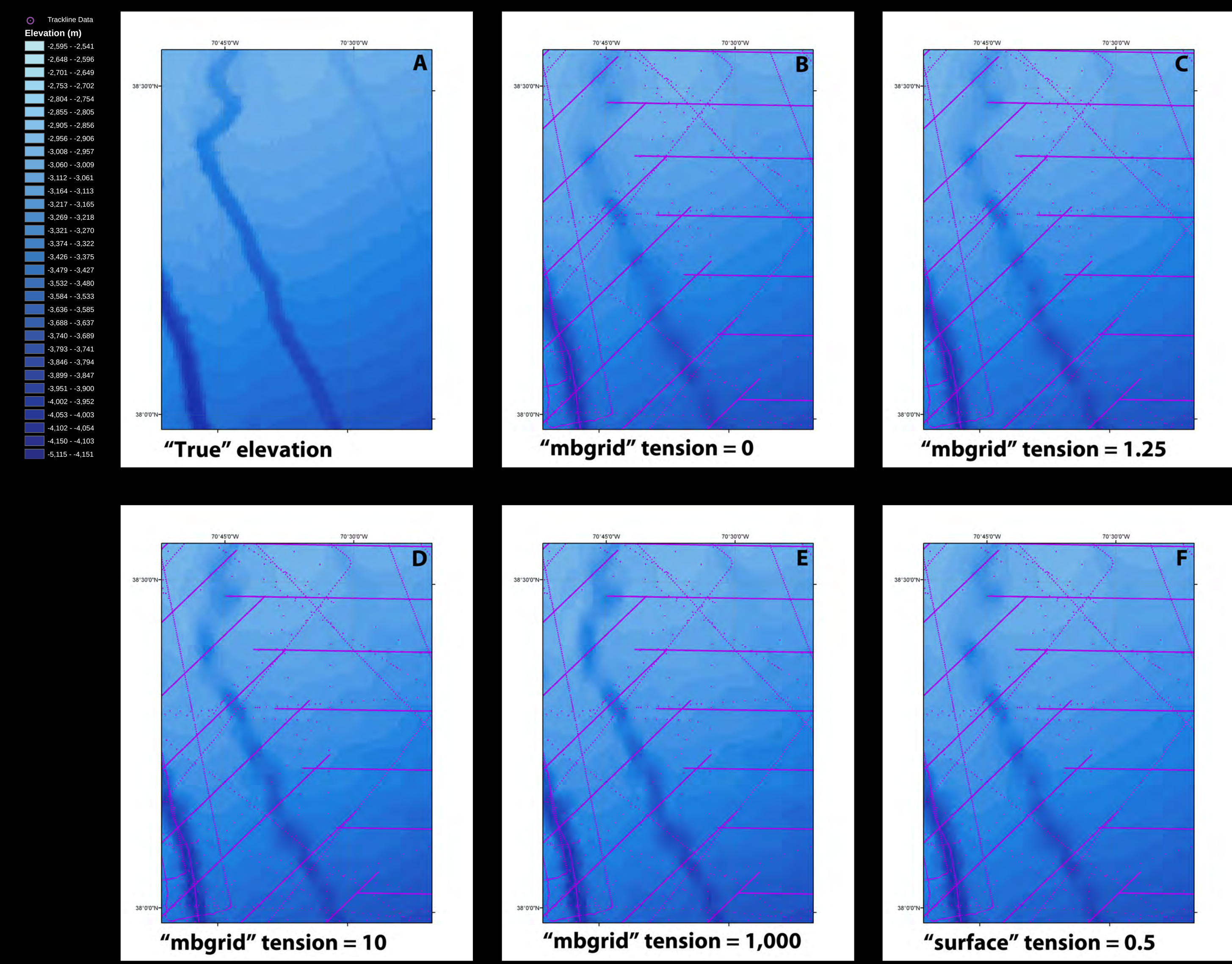

Figure 5. Representation of Carstens Canyon using different spline interpolation methods. Tile A is the "true" elevation grid. A high tension value better represents the linear nature of canyon using "mbgrid" evident in tiles B - E. The tension value has negligible effects on canyon representation using "surface," depicted in tile F.

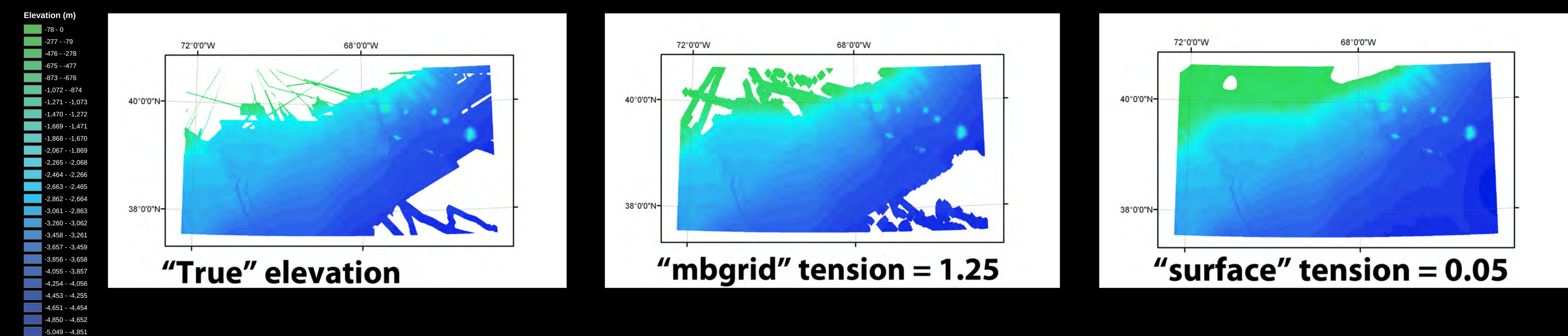

Figure 6. Visual representation of the "true" elevation grid and best -fit spline-interpolations using "mbgrid" and "surface."

Software	Tension Value	Minimum Difference (m)	Maximum Difference (m)	Standard Deviation (m)
MB-System "mbgrid"	1.25 (Range: 0 to infinity)	-667	763	25.05
GMT "surface"	0.05 (Range: 0 to 1)	-577	638	21.55

Figure 7. Statistical analysis of the best-fit spline-interpolations using "mbgrid" and "surface" compared to the "true" elevation for the entire region.

Future Work

Master's thesis project at the University of Colorado at Boulder will study the variations in DEM surfaces created by various gridding techniques (e.g., spline, inverse distance weighting, kriging, tinning, nearest-neighbor) and the impact of these variations on the modeling of tsunami inundation at Crescent City, California. NOAA's Method of Splitting Tsunamis (MOST) model will be used to model inundation from the 1964 Alaska tsunami on each surface.

Website and Contact Information

NGDC multibeam database
http://www.ngdc.noaa.gov/mgg/bathymetry/multibeam.html

NGDC trackline database
http://www.ngdc.noaa.gov/mgg/geodas/trackline.html

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