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Bathymetric Effects on Geoid Modeling

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Bathymetric data over lake areas are not included in previous NGS (National Geodetic Survey) geoid model computations. Mean lake surfaces are used as the bare rock surface during the modeling. This approximation treats the water body as rocks with the same size, and causes errors that can be avoided. This study uses the bathymetric model to rigorously compute the volume of water bodies instead of treating them as rocks, during geoid modeling. To make fair comparisons and show the effects clearly, three sets of geoid models are generated with the same theory currently used at NGS, and with the same parameters. Model-Base is computed without bathymetric information of the water body. In this model, the real water bodies are simply replaced by rocks. Model-Condensed and Model-Density are generated with bathymetric information. The treatments of water bodies are different between the two models, but both are based on the hypothesis of mass conservation. The water bodies are condensed into the equivalent rocks in the Model-Condensed, leading to the geometrical shape changes in the lake area. In the Model-Density, the density of each topographical column bounded by the lake surface and geoid is taken as the average of the density of water and rock bodies included in this column, resulting in the density changes in the lake area. The study area is focused on the Great Lakes area of North America. The geoid model differences between Model-Condensed and Model-Base range from -18 to 25 mm, forming a Gaussian distribution. The distribution of the geoid model differences between Model-Density and Model-Base are not in a Gaussian form, and their values are in the range between -1 and 18 mm. Both the nearby GNSS/Leveling bench marks from US and the multi-year averaged altimetry data are used to validate the results. Consistent geoid model precision improvements of about 2 mm are confirmed around the Lake Superior, which is the deepest and largest lake, over all selected frequency bands of the Stokes's kernel. The numerical results prove the importance of considering water bodies in the determination of a high-accuracy geoid model over the Great Lakes area.