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Geostatistical Gravity Inversion for Estimating Sub-Ice-Bathymetry

Jonas Liebsch[1], Jörg Ebbing[1], Hannes Eisermann[2], and Graeme Eagles[2]
[1]Institute of Geosciences, Kiel University, Kiel, Germany
[2]Alfred Wegener Institute, Geosciences, Bremerhaven, Germany

Sub-ice-bathymetry is an important boundary condition when modelling the evolution of ice shelves and ice sheets. Radar sounding is a proven method to reveal the sub-ice-topography beneath grounded ice. However, it fails to image the bathymetry beneath the floating ice shelves due to the strong radar reflectivity of sea water. As an alternative, the inversion of gravity measurements has been used increasingly frequently in recent years. To overcome the ambiguity of inverse modelling, this method benefits from independent depth constraints derived from direct measurements distributed throughout the model area, such as by active seismic, hydroacoustic, and radar methods.

Here, we present a novel geostatistical approach to gravity inversion and compare it to the classical and more commonly used FFT approach. Instead of only fitting individual points, we also include the spatial continuity of the sub-ice morphology. To do so, we calculate a variogram that fits the available depth measurements and derive a covariance matrix from it. The covariance matrix and an initial bathymetry model obtained by kriging together describe an a-priori probability density. For the inversion, the model bathymetry is related to the measured gravity using a quasi-Newton method, for which the derived probability density serves as the inversion's regularization term. We successfully apply the algorithm to airborne gravity data across the Ekström ice shelf (Antarctica) and compare our results with those of previous studies based on the classical approach. The simplified addition of constraints both for the geometry and the density structure in our approach proves to be advantageous.