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Numerical forward modeling of gravity signals caused by glacier mass changes in Novaya Zemlya

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Within the frame of project ICEAGE (Modeling snow-ice cover evolution and associated gravitational effects with GOCE constraints) a numerical approach to gravity forward modeling has been designed and applied to investigate the impact of glacier changes on the local gravity field. Furthermore, the contribution and applicability of GOCE gravity gradient data to local gravity field solutions was investigated and validated by comparison with the numerical forward modeling approach. This project is jointly performed by the Institute of Navigation and Satellite Geodesy (INAS), Graz University of Technology and the Institute of Digital Image Processing, Remote Sensing Group, Joanneum Research Forschungsgesellschaft mbH (JR).

The study region comprises the Northern Island of Novaya Zemlya situated in the Barents Sea. The most part of the island northwards of 74.5°N latitude with its massive ice sheet, which is third largest worldwide, has been represented in the form of a synthetic model incorporating both, geometrical and density information. A new digital elevation model for the island with a spatial resolution of 70x70 meters was generated using various data sources of topographic information, such as maps, satellite data and the international bathymetric chart of the Atlantic ocean (IBCAO). The distribution of ice, bedrock and ocean density values was initialized in accordance to the empirical density-depth relation offered by Schytt (1958). The combination of density and geometry data led to a model suitable for the forward modeling approach based on prism elements, similar to the concepts applied in gravimetric remove-restore techniques.

The closed formula for prism based geometry yields the gravity effect of a single prism on a distinct computation point. Based on this principle, an evaluation of that formula for the whole model of Novaya Zemlya with computation points placed on the surface topography delivers its contribution to the local gravity field. The model parameters, i.e. density distribution, bedrock topography and ice thickness were tuned, their individual and joint impacts on the local gravity field solution were simulated and studied. The obtained results were compared to local geoid solutions resulting from a least square collocation approach using data from GOCE (Gravity Field and Steady-State Ocean Circulation Explorer), GRACE (Gravity Recovery and Climate Experiment), ArcGP (Arctic Gravity Project) and EGM 2008 (Earth Gravitational Model). A band-pass filter, applied to the forward modeling based solutions, ensured that the gravity fields computed by various different methods are comparable.

Based on the achieved results, the numerical forward modeling of gravity fields enabled the sensitivity analysis of present and future gravity field missions to be performed both, in terms of measurement accuracy and spatial resolution with special emphasis on their applicability to regional monitoring projects in the framework of climate research.