Reprocessing, validation and homogenization of historical marine gravity data from the southern and eastern Baltic Sea – the BalMarGrav project

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BalMarGrav Project Partners

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BalMarGrav PROJECT

The BalMarGrav project, co-financed by the European Union Interreg Baltic Sea Region Programme 2021-2027, aims to improve the insufficient mapping of the gravity field in marine areas of southern and eastern Baltic Sea region. This task is very important due to the decision of the Baltic Sea Hydrographic Commission (BSHC) to implement a common height reference system called the Baltic Sea Chart Datum 2000 (BSCD2000), which is based on a geoid model determined by gravity measurements. A uniform datum in the Baltic Sea region will allow to improve satellite navigation on vessels, in particular, monitoring under-keel clearance, thereby optimizing their routes, reducing fuel consumption and pollution.

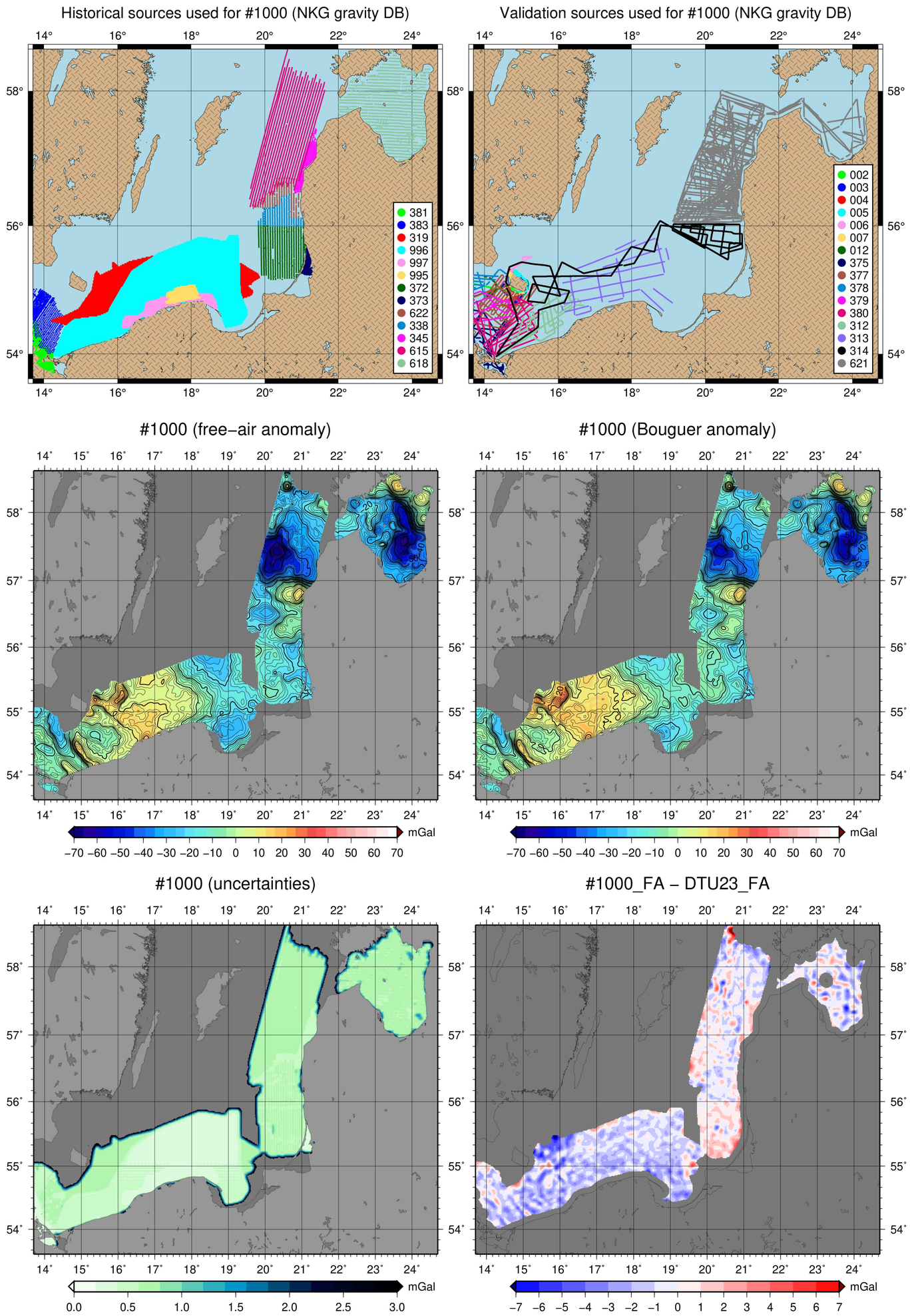
In 1956-1990 multiple marine gravity campaigns were conducted in the coastal areas of Germany, Poland, Lithuania, Latvia and Estonia, mainly with support of the research infrastructure of the Soviet Union. After becoming independent from the Soviet Union and the political transition of former Eastern Block countries, much of this data was forgotten or underutilized. Considering high cost and time consumption of gravity measurements at sea following modern standards, an international network of experts from the Baltic Sea region has been built to reconcile and standardize historical gravity marine data within the BalMarGrav project.

DATA AND METHODOLOGY

Within the BaMarGrav project totally 15 sources of historical gravity data from the Nordic Geodetic Commission (NKG) gravity database (DB) have been examined, 4 of them did not exist in the database previously, and their addition to DB was the result of work done during the project. Historical sources were validated by 16 sources of NKG gravity DB containing modern gravity data (2 of them, publications #314 and #621, are the results of the project). As a result of recalculation procedure, free-air and Bouguer mean gravity anomalies together with uncertainties were calculated on a grid of spatial resolution of 1.2′ x 0.6′ in the region from 13.7° E to 24.7° E and from 53.6° N to 58.6° N.

Bouguer anomalies were recalculated for all sources by adding to free-air anomalies the total topographic effects (including indirect term) computed based on the 2" DEM/bathymetry BalMarGrav model and density values for bedrock/land equal 2670 kg/m^3 and for water/ocean equal 1007 kg/m^3 with integration radius equal 166.7 km. Rectangular prism formulas was used up to ~300 m distance and a vertical subdivision of tesseroids until 6' (~11 km distance). The DEM geometry is assumed on the ellipsoid; the geoid is neglected. The DEM/bathymetry BalMarGrav model were prepared based on the EMODnet Digital Bathymetry (DTM 2022) and EuroDEM patched with MERIT (version 11/2023) models.

Least-squares collocation was used for gridding and uncertainty estimation of recomputed Bouguer anomalies of historical data by Sander Varbla (TalTech, Estonia). GO_CONS_GCF_2_DIR_R6 global geopotential model evaluated up to d/o 300 was used to remove and later restore the long-wavelength gravity signal. Covariances of residual gravity were determined by using the second-order Markov covariance model (signal variance of 55.97 mGal^2 and correlation length of 17.10 km) fitted to the empirical autocovariance curve (5 km distance groups). Assumed uncertainties of the input data (determined from validations procedure) varied from 1.0 to 2.4 mGal. Grid node value prediction was done by using 100 closest points to a grid node in each quadrant. Extrapolation was allowed up to 6 km from the nearest available data point. Gridded free-air anomalies were obtained by restoring the topographic effects with uncertainties assumed equivalent to the Bouguer anomalies.



HOMOGENIZED HISTORICAL GRAVITY DATA

Homogenized historical gravity data has been added to the NKG gravity DB under the extraction licence „product_balmargrav" (source #1000) and is available to the public upon an e-mail request to Gabriel Strykowski (gs@space.dtu.dk).

STATISTICS OF DIFFERENCES

The homogenized historical gravity model (free-air anomalies) has been compared with FAMOS gravity models, altimetric model and comibined global gravity model EIGEN-6CN (https://icgem.gfz-potsdam.de/).

Model used for comparison	Mean [mGal]	Median [mGal]	Std [mGal]	Min [mGal]	Max [mGal]	Comments
BKG5D_FA	-0.1	-0.1	1.1	-8.5	+12.0	Gravity model (FAMOS project)
DTU_FA	-1.1	-1.0	1.3	-13.9	+12.7	Gravity model (FAMOS project)
LM9F_FA	-0.1	-0.1	1.1	-8.6	+13.2	Gravity model (FAMOS project)
TUT3_FA	-0.2	-0.1	1.1	-9.3	+13.2	Gravity model (FAMOS project)
DTU23_FA	-0.8	-0.8	1.5	-7.7	+9.6	Altimetric model (> 10 km from coast)
EIGEN-6CN	-0.8	-0.9	2.0	-13.8	+10.8	Combined global gravity model

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