Assessing the spatial representativeness of water storage variations from superconducting gravimeter residuals by regional CG-6 surveys

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EGU23-14115

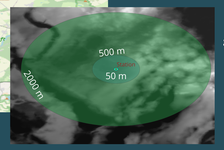
Motivation

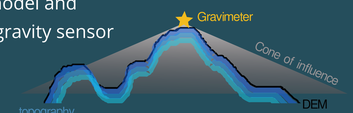
The main objective of TerraQ (subproject C05) is to evaluate the feasibility of an added value of terrestrial gravity observations in combination with GRACE and GNSS (see presentation by Wöhnke et al). The idea is to use the terrestrial data of both GNSS and gravimetry to improve spatio-temporal resolutions of GRACE solutions.
Consequently it is necessarry to know how representative terrestrial gravity measurements at single points are for a certain region around the instrument.
This study asseses the spatial representativeness of an example site equipped with a superconducting gravimeter (iGrav) by analysing spatially distributed relative gravity surveys as well as static site features of the different survey points.

Topographic Admittance Factor

- conversion of gravity to water storage changes
- infinite horizontal layer (Bouguer) has a conversion factor of 0.419 nm/s² / mm
- topographic admittance is calculated from gravity attraction components in 3D grid
- grid construction based on digital elevation model and distance of mass change with respect to the gravity sensor

Topographic admittance factors in nm/s² / mm of water, calculated at each relative gravity survey station (black stars). Base station at iGrav is indicated.

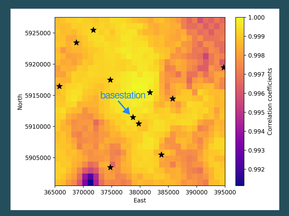




The cone of influence defines the area of sensibility (=footprint) of the gravimeter. Its highest sensitivity is in the vertical axis. Size and shape of the cone depend on the percentage of signal considered (typically 95%). Water storage changes in topography parallel layers (based on a DEM) have different influences on the gravity observations based on their location relative to the sensor.

Example setup showing the nested grid approach around a survey station. Each of the 3 circles has a different grid discretization in x,y,z direction and uses different formulas to calculate the gravity attraction components for each grid cell.

Regional Spatial Features

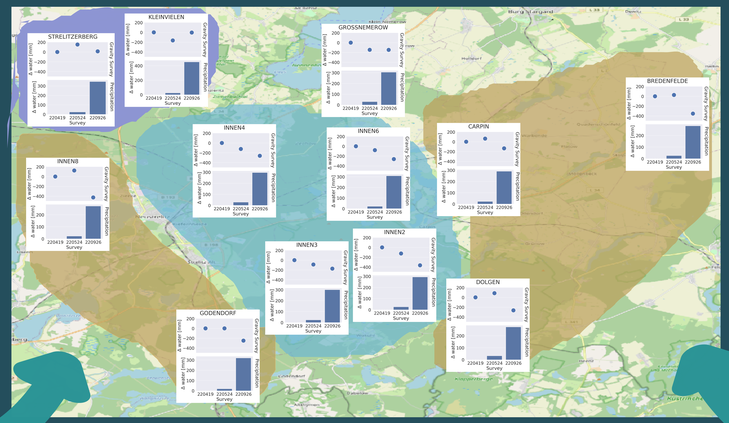


Correlation coefficients of 1 km x 1 km grid cells of cumulative precipitation with the precipitation in the grid cell of the base station. Black stars show the relative gravimetry survey points.

- DWD Radolan precipitation grid cells (1 km x 1 km) in survey domain highly correlate with cell of base station
- (water) mass input within survey domain is consequently rather heterogeneous
- Further evaluation of spatial features will include:
  - local terrain shape → water accumulation
  - soil properties → water storage and transport
  - site properties → water storage and transport
  - land-use → water surface dynamics

Base station of the local gravity survey network in the Müritz National Park (North Eastern Germany). The permanently measuring superconducting gravimeter (iGrav) in its green field enclosure is visited by mobile gravimeters AQG (white cylinder) and CG-6 (orange-grey cubes).

Trends of total water storage changes indicate different areas of hydrological system responses



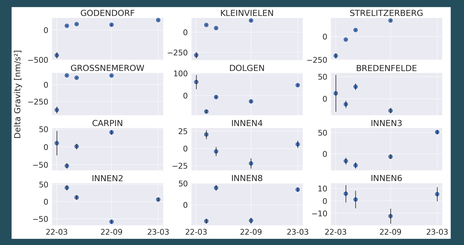
Results of the "Workflow of Assessment" (up to step 4; box on the lower right):
Each plot shows gravity surveys based water storage changes in [mm] for different survey dates at the respective location of each survey point.
Furthermore station specific cummulative precipitation between survey dates are shown for all stations.
Areas of different trends in total water storage changes are indicated with different background colors on the map.

Take Home Messages

- relative gravity surveys are helpful to look at spatially distributed water storage changes
- continuous gravity observations enable a temporal connection between surveys
- site-specific topographic admittance factor needed to convert gravity to WSC
- increased gravity survey accuracy due to decrease of surveyed points and increase in repetitions at each point: overall σ of 5 nm/s² (= 2 mm water)
- precipitation not sufficient to explain different trends at individual survey sites
- complete water balance and spatial site features necessary to complete assessment

Adjusted CG-6 Survey Data

- 5 surveys since March 2022
- each survey with two Scintrex CG-6
- survey design update in 2023:
  - less points with more repititions (for improved accuracy)
- device drift handling:
  - long-term: estimated in lab
  - transportation: within adjustment
- least-squares network adjustment: gravity differencs between point and base station data from both gravimeters used in one joint adjustment



Results from 4 relative gravity surveys, using two Scintrex CG-6 gravimeters. Adjusted gravity differences with respect to the base station (iGrav) and reduced by their station mean value.

Workflow of Assessment

1. network adjustment
   CG-6 CG-6 → Δg
   network adjustment of realtive gravity survey data: data of both field gravimeters used in a joint adjustment; results: gravity differences of individual survey points to the base station (iGrav)
2. convert Δg (topographic admittance)
   normalize obtained gravity differences by point specific topographic admittance factor; results: individual terrain-based spatial water storage changes at survey periods
3. combine
   iGrav + time
   combine differences with continuous iGrav observations; results: connection in time of temporally-spaced survey results
4. compare
   time ? =
   compare water storage time series at survey points with cummulative precipitation data; (next step): use site-specific local water balance for comparison
5. extract and analyse
   next steps
   time +
   extract information of survey point specific features for join assessment; (sensitivity analsis of features, correlation lengths, etc.)