Deutsches Geodätisches Forschungsinstitut
Institute for Astronomical and Physical Geodesy
Department of Civil, Geo and Environmental Engineering
Technical University of Munich

ORG4heights

Optimally combined regional geoid models for the realization of height systems in developing countries

Verena Lieb[1], Michael Schmidt[1], Martin Willberg[2], and Roland Pail[2]

[1] TUM Deutsches Geodätisches Forschungsinstitut (DGFI-TUM), Munich, Germany (mg.schmidt@tum.de)
[2] TUM Institute for Astronomical and Physical Geodesy (APG), Munich, Germany

Motivation

Revolutionized knowledge of the Earth's gravity field, especially since

Geodetic application: e.g. physical height (vertical reference) systems
Regional problems: deficit in developing or newly industrializing countries; construction, infrastructure, industrialization suffer
Global consequences: global environmental change; shortage of water and energy resources; grow of megacities

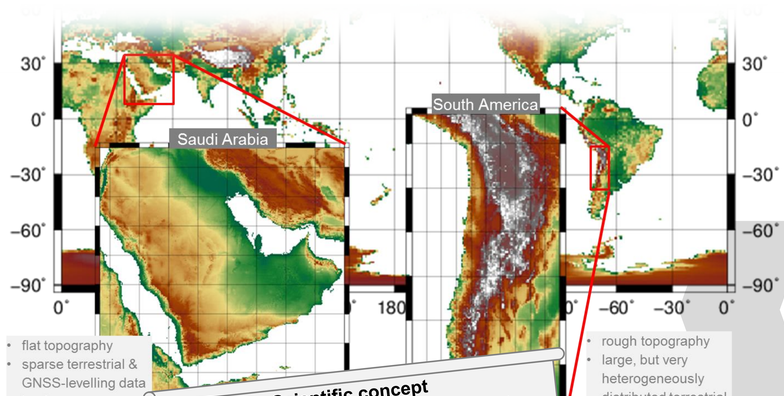
-> need for accurate & easily accessible physical height information

Aim

Formulation of a general scientific concept how to
(1) optimally combine all available data sets,
(2) estimate realistic errors, and
(3) establish and unify physical height systems based on resulting regional gravity models.

Scientific challenges

- missing reliable and high-quality terrestrial gravity data, data gaps
- stochastic & systematic errors, omission errors
- varying topography
- missing data in coastal regions
- unknown standards and reference frames



- flat topography
- sparse terrestrial & GNSS-levelling data basis

- rough topography
- large, but very heterogeneously distributed terrestrial data base

Scientific concept

❑ … how to optimally combine global models & terrestrial regional gravity information.
❑ … how to compute regional geoid models.
❑ … how to establish a national height system & link it to a global reference system
… w.r.t. constraints, limitations and special boundary conditions of developing & newly industrializing countries

Guideline for further use in science and administration

Project structure

Work packages (WP), leading institution (colour coded): APG, DGFI-TUM

WP 100: Data Sets (APG)

gravity data

global models
derived from GRACE & GOCE

global & regional data sets
- terrestrial, airborne, and shipborne gravity data
- GOCE gravity gradients
- altimetry data

additional data
- tide gauges
- GNSS levelling heights
- topographic models

WP 110: Acquisition of Data Sets (APG, DGFI-TUM)

Study area 1: **South America**
- large data base
- rough topography

Study area 2: **Saudi Arabia**
- sparse data sets
- flat topography

WP 120: Quality Assessment, Intercomparison and Validation (APG)

WP 130: Stochastic Modelling (DGFI-TUM)

WP 200: Methodology & Simulation (DGFI-TUM)

WP 210: Review of Existing Methods and Approaches (DGFI-TUM, APG)

WP 220: Identification of Appropriate Modelling Tools (DGFI-TUM, APG)

WP 230: Development of a Simulation Environment (APG)

WP 240: Regional Gravity Field Modelling (DGFI-TUM)

WP 250: Height Systems, Data Combination & Omission Errors (APG, DGFI-TUM)

WP 300: Height System in Developing Countries (DGFI-TUM, APG)

WP 310: Case Studies (DGFI-TUM, APG)
Study area 1: **South America**
Study area 2: **Saudi Arabia**

WP 320: Validation (APG, DGFI-TUM)
Study area 1: **South America**
Study area 2: **Saudi Arabia**

WP 400: Generalized Scientific Concept (APG, DGFI-TUM)

Acknowledgements
The authors want to thank the DFG (Deutsche Forschungsgemeinschaft) for funding the project ORG4heights (April 2016 – March 2019).

Related publications:
Lieb et al. (2016): Combination of various observation techniques for regional modeling of the gravity field. Journal of Geophysical Research 121(5), 3825-3845, 10.1002/2015JB012586.
Pail et al. (2010): On the combination of global and local data in collocation theory. Studia Geophysica et Geodaetica, 54:2, 195-218, doi: 10.1007/s11200-010-0010-1.
Schmidt et al. (2007): Regional Gravity Modelling in Terms of Spherical Base Functions. Journal of Geodesy, 81, 17-38, 10.1007/s00190-006-0101-5.

Gravity measurements & spirit levelling
+ countries with good geodetic infrastructure: cm-accuracy
- laborious, expensive

➢ not affordable for developing countries
➢ local datum (>100 national height systems)
➢ different definitions of height systems

GNSS measurements & altimetry
- spatially limited
+ globally available
+ "inexpensive"

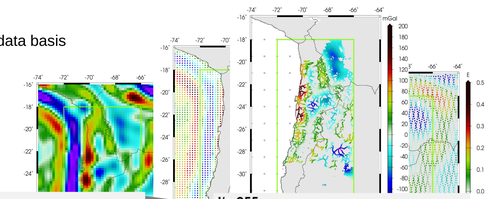
➢ connection & unification by GNSS-/ ocean-levelling

Satellite gravimetry and combination of gravity data

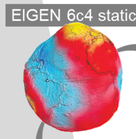
➢ combination of global models and terrestrial regional gravity information

Satellite only models (e.g. GOCO series):
- limited spatial resolution (70-80 km)
- omission error (missing spectral information: 20-40 cm)

Combined models (e.g. EGM2008):
- high resolution only in regions with terrestrial data basis



EIGEN 6c4 static



validation data
d/o 255 grid 0.2°: N
d/o 2047 grid 0.2°: N

simulated observations

d/o 255
1) grid 0.2° : Dg (h0), Dg (htopo), Vzz; N
2) orig. pos. : Dg (hocean), Dg (hmeas), Vzz (horbit), N

d/o 2047
1) grid 0.1° : Dg (h0), Dg (htopo), Vzz; N
2) orig. pos. : Dg (hocean), Dg (hmeas), Vzz (horbit), N

+

white noise
- Dg, N: : 2 mGal, 5 mGal, 10 mGal
- Vzz : 0.2 mE, 1 mE

closed-loop scenarios

d/o 255
1) grid 0.2° : 4 single (noise-free), 2 combi scenarios (noisy)
2) orig. pos. : 2 combi scenarios (noisy)

d/o 2047
1) grid 0.1° : 1 combi scenario (noisy)
2) orig. pos. : 1 combi scenario (noisy), …

optimized SBF – MRR approach

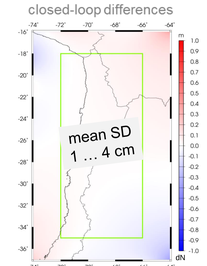
SBF – MRR
- level 8 vs. 11
- Shannon vs. Blackman
- max. modeling degree
- VCE: initial values (noise level), stop criterion (iteration), partial redundancy, condition number, eigenvalues, prior information, …
- covariances of coefficients
- …

LSC
- d/o 255 vs. 2047
- analytical vs. empirical covariance function
- iterative noise covariance matrix
- separation of terrestrial data
- manual weighting of GOCE data
- remove-restore procedure
- …

regional gravity field modeling approaches

d/o 255 grid 0.2° — **dN** 4 single + 4 combi scenarios
d/o 2047 grid 0.2° — **dN** 2 combi scenarios
…

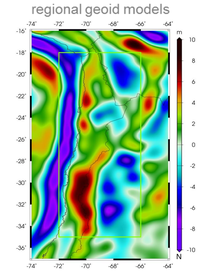
closed-loop differences



- handling of data gaps,
- influence of edge effects,
- choice of tools from 3 boxes
- …

➢ minimizing square of residuals

regional geoid models



PICO5b.11
Willberg M. et al.: Study of Least Squares Collocation and Multi-Resolution Representation for Regional Gravity Field Modelling, G1.2: EGU2017-13135

EGU General Assembly 2017
Vienna, Austria
23 – 28 April 2017