Final Report

Improved Gravity Database for Africa employing variable crustal density

Hussein A. Abd-Elmotaal

Minia University, Faculty of Engineering
Civil Engineering Department, Minia 61111, Egypt
hussein.abdelmotaal@gmail.com
http://scholar.google.com/citations?user=1yCeSZwAAAAJ

One of the main tasks of physical geodesy is the determination of the geoid, which is directly connected with the theory of equipotential surfaces. Besides the scientific interest of determining the geoid, it serves for realizing a height reference system necessary, e.g., for monitoring temporal changes of sea level, geophysical exploration, and monitoring vertical motions and plate tectonics.

The International Association of Geodesy (IAG) has recognized in its 2015 Resolution No. 1, entitled "The definition and realization of an International Height Reference System (IHRS)", that to determine and to investigate the global changes of the Earth, geodetic reference systems with long-term stability and worldwide homogeneity are required. IAG also recognized that detecting the sea level change of a few millimeters per year can only be achieved when a stable spatial reference with globally high accuracy over a long period of time is realized. The IAG resolved conventions for the definition of an IHRS with the vertical reference level as an equipotential surface of the Earth gravity field, the geoid, and fixed the corresponding geopotential value W0 with a specific number. The spatial position of this reference surface with respect to the body of the Earth has globally to be determined for realizing the IHRS.

IAG has launched a regional sub-commission entitled "Gravity and Geoid in Africa", chaired by Hussein Abd-Elmotaal (https://com2.iag-aig.org/sub-commission-24). The IAG African Gravity and Geoid sub-commission has a number of African and international geodesists as steering committee of that sub-commission. They all work as volunteers and IAG provides moral and formal (non-financial) support. One of the main goals of the African Gravity and Geoid sub-commission is to determine the most complete and precise geoid model for Africa that can be obtained from the available data sets.

The currently available gravity data set for this project is visualized in Fig. 1. The green colour refers to the land data, the blue colour refers to the shipborne data and the magenta colour refers to the altimetry data.

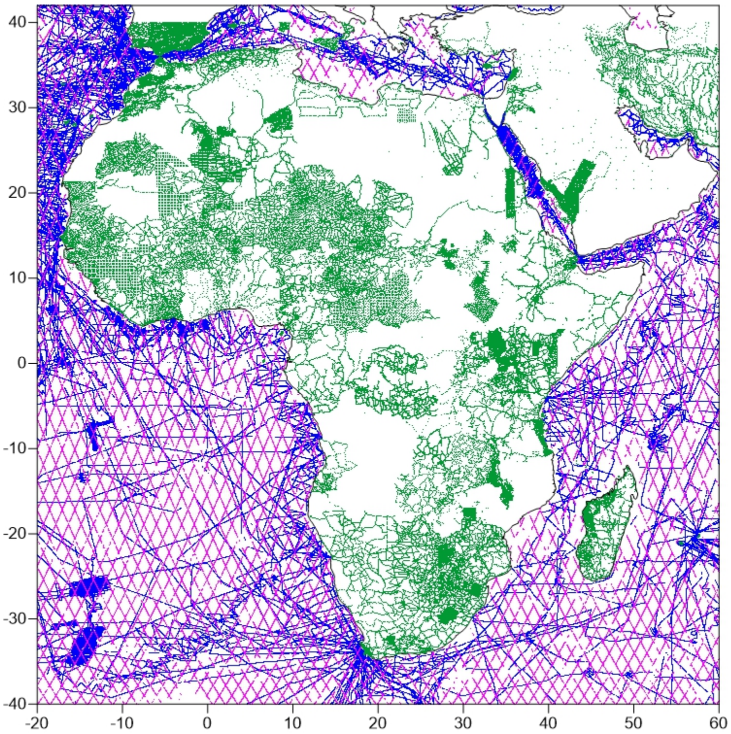

Fig. 1: Distribution of the gravity data for Africa.

Figure 1 shows the irregular gravity data distribution with very large gaps, especially on land, which is extremely challenging. The total number of gravity data stations on land is about 130,000 stations and on sea is about 1.3 million.

Simple interpolation of the gravity data does not add new information at the large data gaps. Accordingly, the variable crustal density model produced by the University of New Brunswick (Steng et al., 2019), Fig. 2, has been employed in the framework of the non-ambiguous window remove-restore technique (Abd-Elmotaal and Kühtreiber, 2003), aiming for better smoothed reduced anomalies to minimize the interpolation errors. The variable crustal density model is available as a 30″×30″ grid.

Figure 2 shows that the variable crustal density model assigns the great lakes with density equals 1.0 g/cm^3, and the oceans with density equals zero. This causes a misleading when computing the effect of topographic masses in the window remove-restore technique. Accordingly, a density model compatible with the computation of the effect of topographic masses within the window remove-restore technique has been developed. This has been achieved by setting the density of the great lake-areas to 2.67 g/cm^3, and the density of the oceans to 1.027 g/cm^3. A set of Digital Density Models DDMs is needed for the computation of the effect of the topographic masses. This has been achieved by the block average operator technique. Figure 3 shows the 3′×3′ developed Digital Density Model for Africa.

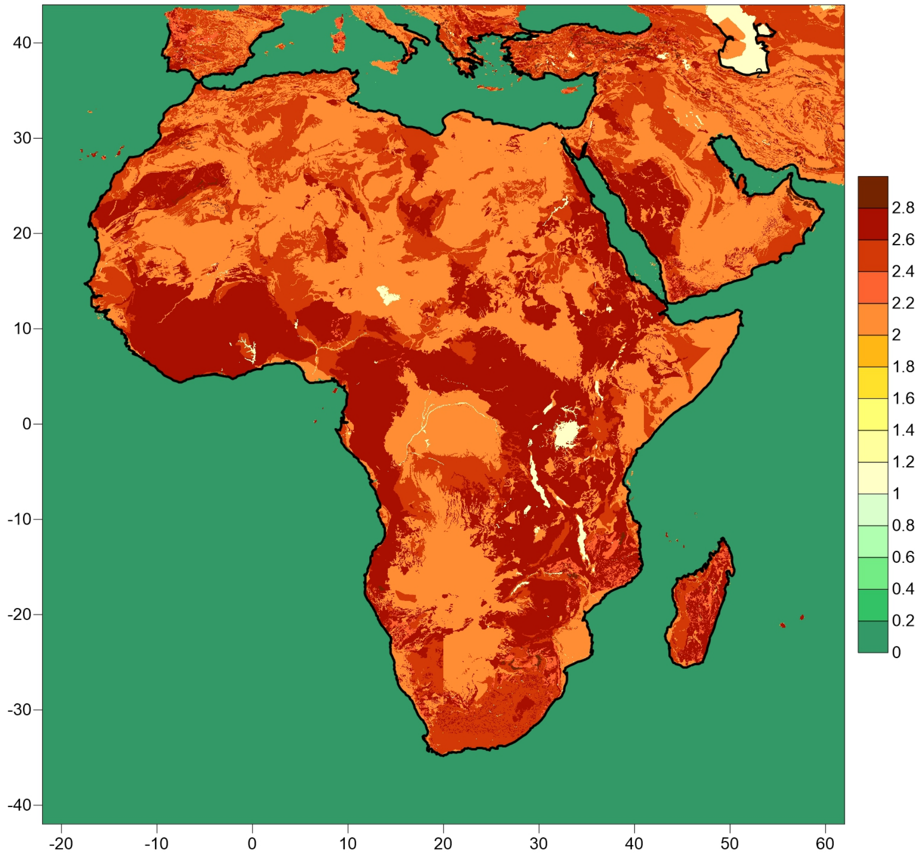

Fig. 2: The 30″×30″ variable crustal density model for Africa, after (Steng et al., 2019). Units in [g/cm^3].

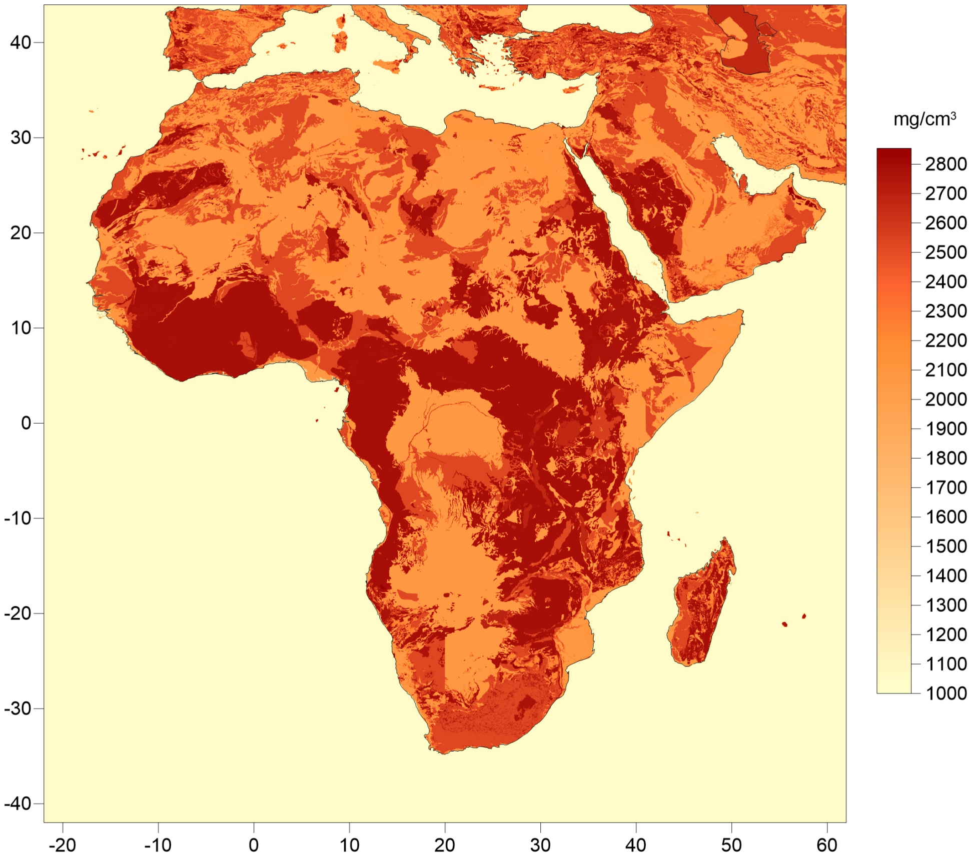

Fig. 3: The 3′×3′ developed Digital Density Model for Africa. Units in [mg/cm^3].

Figure 4 shows the window-reduced anomalies for Africa using the Digital Density Models. The white pattern signalises reduced anomalies below 10 mgal in magnitude. Figure 4 shows that the density values given in some parts on land (such as Morocco, South African and Iran) are, to a great extend, unrealistic. Figure 4 will be used as the basis for improving the accuracy of the Digital Density Models for Africa. This task will be carried out with the cooperation of the German geodesist in Karlsruhe Institute of Technology, hopefully in the near future.

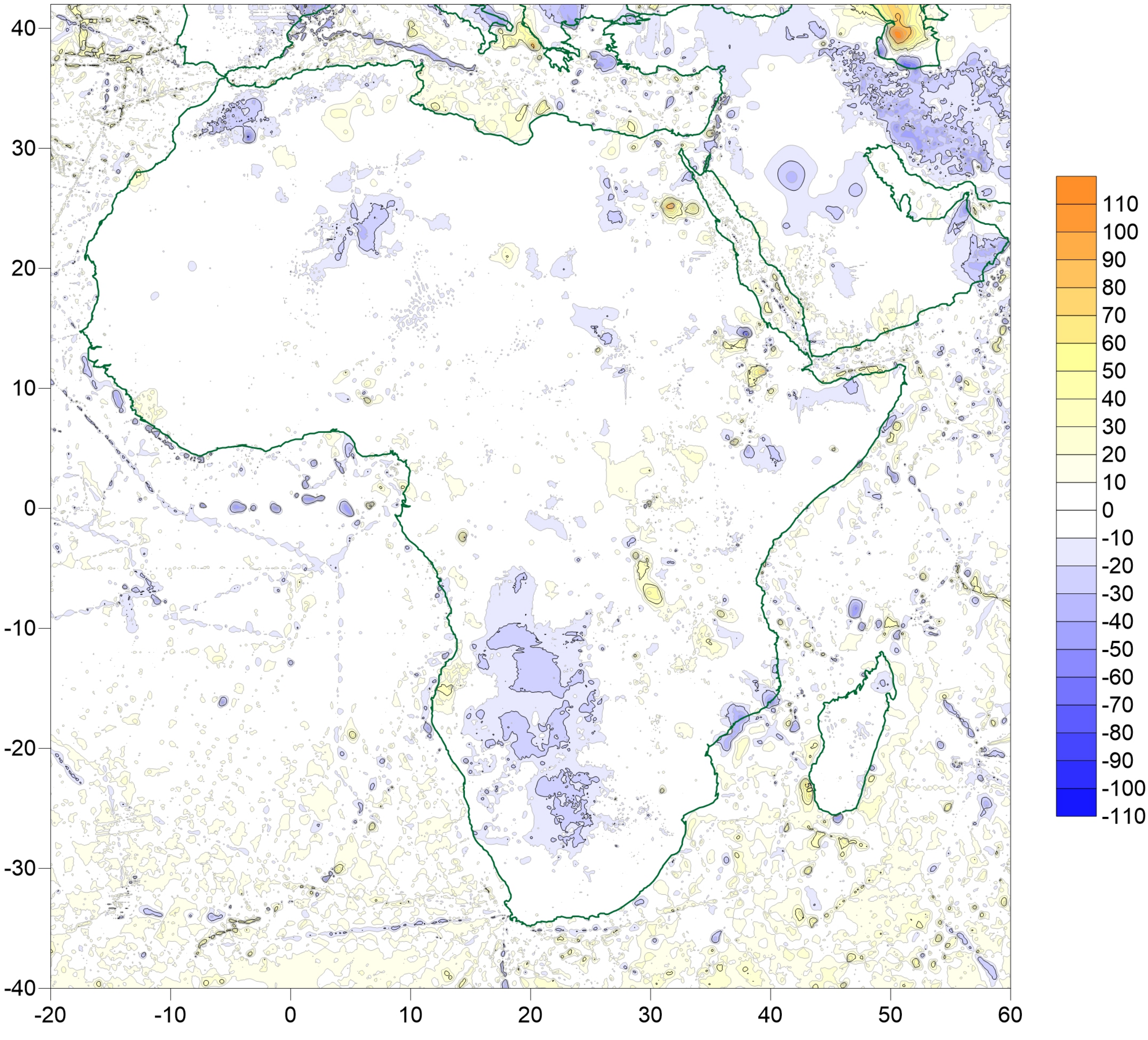

Fig. 4: Window-reduced anomalies for Africa using the Digital Density Models. Units in [mgal].

Further cooperation with my host professors, Prof. Dr. Hansjörg Kutterer and Prof. Dr. Bernhard Heck and their institute is planned at different scales. One of which is that we are going to apply for a Material Resources Grant funded by DAAD. Another one is that we are going to submit a joint project proposal supported by the Egyptian STDF and the German DAAD.

Finally, I would like to express my thanks to the KIT for supporting this research project. I wish also to thank both Prof. Dr. Hansjörg Kutterer and Prof. Dr. Bernhard Heck and their coworkers, in particular Dr. Kurt Seitz, for their cooperation and the friendly atmosphere I have had during my stay in Karlsruhe.

References

Abd-Elmotaal, H. and Kühtreiber, N. (2003) Geoid Determination Using Adapted Reference Field, Seismic Moho Depths and Variable Density Contrast. Journal of Geodesy, **77**, 77–85, https://doi.org/10.1007/s00190-002-0300-7.

Sheng, M.B., Shaw, C., Vaníček, P., Kingdon, R.W., Santos, M. and Foroughi, I. (2019) Formulation and validation of a global laterally varying topographical density model. Tectonophysics, **762**, 45–60, https://doi.org/10.1016/j.tecto.2019.04.005.