Utilisation of Geodesy in infrastructure and Hydrology using GOCE and GRACE Satellite missions

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Abstract
Geoid modelling in Sudan suffers from the lack of necessary ground measurements such as country-wide GNSSlevelling and terrestrial gravity data from neighbouring countries. Most of the geodetic measurements conducted during the past 4 decades are either not officially released or not easily accessible. In this study, we use available GNSS-levelling data, terrestrial gravity data and recent global geopotential models (GGMs) from the Gravity field and steady-state Ocean Circulation Explorer (GOCE) mission. The optimization of local and global datasets has been done in three steps based on the minimization of the root mean root (RMS) of their differences. Firstly, the GGM-based undulations are compared versus the GNSS-levelling undulations. There, GOCE satellite-only models based on the direct, space-wise and time-wise methods (GOCE-DIR-R4, GOCE-DIR5, GOCE-SPW-R4 and GOCE-TIM-R5) show the best agreement at degree and order (d/o) 222. Secondly, the accuracy of the local gravity data has been estimated by means of spherical radial basis functions (SRBF) using the Poisson kernel. The optimal minimization of the RMS of the differences between the real and predicted values based on an optimal radial depth of 375 m was 3 mGal. Lastly, the parameters obtained from the previous steps are combined to estimate the least-squares parameters for the modified Stokes formula. The optimum spherical cap radius around the computation point was found to be 1.74˚. The parameters have been successfully estimated by combining data information from GOCE-DIR-R4 and local gravity data and σ0 to compute the gravimetric geoid. The final gravimetric geoid solution is evaluated by GNSS-levelling data. Best-fit comparison between them is found to be 18 cm after fitting by a 7-parameter model. This result shows an improvement of about 10 and 4 cm compared to the existing models computed in 2008 and 2014, respectively.

On the hydrological part, the legacy of the GRACE (Gravity Recovery and Climate Experiment) dedicated satellite mission is now up to 170 monthly gravity field solutions available from different geodetic centers (CSR, GFZ and JPL) for GRACE satellite data processing. The accumulated satellite data make it possible to observe the periodic and temporal hydrological changes in the earth over different spans of time. In this study, we utilize the least-squares spectral method to analyze mass changes over Sudan to determine the major temporal variations in that region. GRACE results are compared to the hydrology model GLDAS, analysis for the mass variations is also discussed. We utilise the least-squares spectral method to analyse mass changes in Eastern Sudan and to determine the major temporal variations over the region includes the Dinder National Park area close to Rahad seasonal river which is one of the Blue Nile tributaries. It was noticed that the annual cycles show large amplitude over the study area. The three GRACE models (CSR, GFZ and JPL) based on spherical harmonic coefficients have presented similar results. GRACE results are compared to GLDAS hydrology model and showed good agreement between CSR and JPL solutions. Local annual changes from April 2002 until December 2015 are noticed over the eastern part of Sudan and in the sources of the Nile in Ethiopia and Uganada where it reaches 12 mm by the GRACE models. The time variations of the equivalent water layer GRACE data was observed over the Dinder region. An increase of the water mass over 14 years is detected. The trend of water variations over 15 years shows an increase of 0.33 mm/ year over the investigated region.