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On the contribution of dedicated gravity satellite missions to the modelling of the Earth gravity field – A case study of Ethiopia and Uganda in East Africa

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Abstract: Since the first decade of this millennium, the three dedicated gravity satellite missions (DGSMs): CHAMP (Challenging Minisatellite Payload), GRACE (Gravity Recovery and Climate Experiment) and GOCE (Gravity field and steady-state Ocean Circulation Explorer) had remarkably contributed to the modelling of the Earth's gravity field and its temporal variations. Moreover, in 22 May 2018, the GRACE-FO (GRACE Follow-On) has been launched to continue the measurements of GRACE satellite mission. On the basis of data from those DGSMs, Global Geopotential Models (GGMs) are continuously developed. The main aim of this research is to evaluate the recent GGMs and assess the contribution of DGSMs to the modelling of the Earth's gravity field over East Africa. Gravity functionals, e.g. quasigeoid height and gravity disturbance, obtained from recent GGMs developed with the use of data from DGSMs were evaluated using terrestrial gravity data available in Ethiopia and GNSS/levelling data in Uganda. The results obtained were analysed and discussed. The main findings reveal an improvement of ca. 40–50% on the modelled gravity field from GGMs that include data from GOCE satellite mission.

Keywords: East Africa, Global Geopotential Model, gravity functionals, dedicated gravity satellite missions

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1. Introduction

The modelling of the Earth's gravity field is one of the main tasks of geodesy. Usually, the Earth's gravity field can be determined by integrating gravity data measured at different scales. Dedicated gravity satellite missions (DGSMs), such as CHAMP (Challenging Minisatellite Payload: July 2000–September 2010) (Reigber et al., 2002), GRACE (Gravity Recovery and Climate Experiment: March 2002 – October 2017) (Tapley et al., 2004) and GOCE (Gravity field and steady-state Ocean Circulation Explorer: March 2009 – November 2013) (Floberghagen et al., 2011) have made remarkable contribution to the modelling of long wavelength components of the Earth's gravity field, e.g. up to degree and order (d/o) 300 (e.g. Gatti et al., 2016). The recently launched GRACE-FO (GRACE Follow-On) gravity satellites[1] are also expected to improve the Earth's current static and time-varying gravity field. With the availability of almost continuously updated data from dedicated satellite gravity missions, there is a growing research interest for the development of satellite-only Global Geopotential Models (GGMs) and combined GGMs as well as accuracy evaluation of the GGMs. Many studies have been carried out to validate the accuracies of the GGMs on global, regional and local scales (Abd-Elmotaal, 2009; Benahmed, 2009; Krynski and Kloch, 2009; Merry, 2009; Dawod et al., 2010; Hirt et al., 2011; Sprlák et al., 2012; Abd-Elmotaal and Makhloof, 2013; Bomfim et al., 2013; Voigt and Denker, 2014; Abd-Elmotaal, 2015; Elsaka et al., 2016; Gomez et al., 2017; Godah et al., 2018; Odera, 2019). Many international working groups such as the International Gravity Field Service (IGFS) and the Commission 2 of the International Association of Geodesy (IAG) have intensively assessed the accuracy of the Earth Gravitational Model 2008 (EGM2008; Pavlis et al., 2012) and GOCE-based geopotential models (Newton's Bulletin, 2009; 2015) using an independent data such as terrestrial gravity data and GNSS/levelling data.

In the large part of Africa, the Earth's gravity field is still not well determined at all wavelengths as well as the GGMs are not adequately evaluated. The African Gravity and Geoid sub-commission of the Commission 2 "Gravity field" of the International Association of Geodesy (IAG) is currently working to obtain the most appropriate gravity data and to develop a precise geoid model for Africa. In order to meet this expectation, at least, at the long wavelength scale, a GGM of high accuracy is required. The main aim of this study is to evaluate the accuracy of recent satellite-only GGMs and combined GGMs as well to assess the contribution of data from dedicated gravity satellite missions to the modelling of the Earth's gravity field over Ethiopia and Uganda in East Africa.

2. Study area and data used

In this investigation, regions of Ethiopia and Uganda were chosen as a case study (Fig. 1). GNSS/levelling data from a few GNSS/levelling stations, i.e. seven stations, located within major cities in Uganda, mostly in the southern part (cf. Fig. 1), were used. The levelling heights of those stations were determined by spirit levelling referred to the Egyptian Benchmark BM 9029 that related to the historical Alexandria mean sea level. The ellipsoidal heights at those stations were obtained from GNSS survey conducted in 48–114 hours observing sessions during the period from 10 to 18 February 2012. Unfortunately, no information about the accuracy of GNSS/levelling data in Uganda is

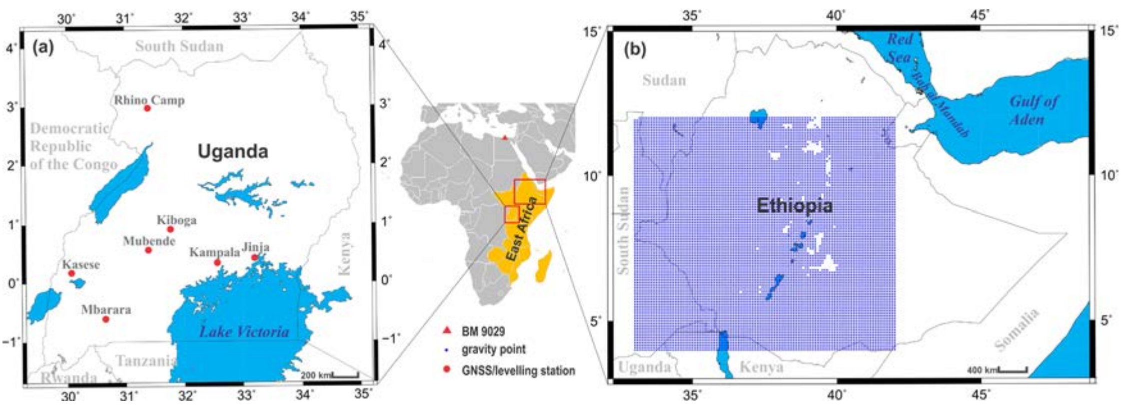

Fig. 1. Study areas located in East Africa defined on the basis of the United Nations Statistics Division-Standard Country and Area Codes Classifications[2], (a) the area of Uganda, and (b) the area of Ethiopia, as well as the distribution of airborne gravity and GNSS/levelling data

[1] cf. https://gracefo.jpl.nasa.gov/
[2] see https://unstats.un.org/unsd/methodology/m49/

Table 1. Main characteristics of GGMs used in this study

	Name in ICGEM	N_{max} (d/o)	GOCE data	GRACE data	Terrestrial and altimetry data	Time of releasing	Reference
Combined GGMs	EGM2008	2190	–	~3.5 years	5′×5′ terrestrial gravity data + Fill-in + SIO/ NOAA and DNCSC07	2008	Pavlis et al., (2012)
	EIGEN-6C4	2190	~4.5 years	~10.0 years	DTU10 + DTU12 + EGM2008	2014	Förste et al., (2014)
	GECO	2190	~5.0 years	~3.5 years (from EGM2008)	EGM2008	2015	Gilardoni et al., (2016)
	SGG-UGM-1	2159	~1.7 years	~3.5 years (from EGM2008)	EGM2008	2018	Liang et al., (2018)
Satellite-only GGMs	SPW-R5	330	~5.0 years	–	–	2017	Gatti et al., (2016)
	DIR-R5	300	~5.0 years	~10.0 years	–	2014	Bruinsma et al., (2013)
	TIM-R5	280	~5.0 years	–	–	2014	Brockmann et al., (2014)
	IfE_GOCE05s	250	~5.0 years	–	–	2017	Wu et al., (2016)
	NULP_02s	250	~5.0 years	–	–	2017	Marchenko et al., (2016)
	IGGT_R1	240	~0.2 years	–	–	2017	Lu et al., (2018)
	GOSG01S	220	~1.7 years	–	–	2018	Xu et al., (2017)

available. However, the fit, in terms of standard deviation of the differences, of geoid heights obtained from the EGM2008 to the corresponding ones obtained from GNSS/levelling data is estimated to be 0.255 m (Abeho et al., 2014). All GNSS/levelling stations are located at an elevation height ranging from 990 to 1460 m above the mean sea level. The only exception is for the GNSS/levelling station at Rino Camp city which is located at elevation height of ca. 631 m above the mean sea level (ibid).

For Ethiopia, gravity disturbances from a regular grid of 5′×5′ spatial resolution covering the area bounded by the parallels of 4°N and 12°N and the meridians of 33.1667°E and 42°E, have been used. The elevation of this area above the mean sea level is ranging from 99 to 2992 m with a mean elevation of 1225 m. Those gravity disturbances were determined from airborne gravity survey acquired with along-track resolution (750–1125 m) and track spacing of 18 km during the period between 2006 and 2008 (Bedada, 2010). The estimated accuracy of these gravity disturbances is 2.6 mGal (Olesen and Forsberg, 2007). The gravity disturbance and normal gravity are computed as a function of an ellipsoidal height referred to WGS 84. Now, the accuracy of the geopotential heights or geoid undulations determined using this detailed local gravity data in combination with a GGM is at the centimetre level as estimated over small region in Ethiopia (Bedada, 2010). This high resolution local airborne gravity data in Ethiopia was incorporated in the development of the EGM2008; locally this global model has demonstrated a better accuracy (3–5 cm) compared to its global estimate (Bedada, 2010; Bekele, 2013; Derese, 2013; Worku, 2013; Geremew, 2017).

In this study, seven of the recent satellite-only GGMs and four ultra-high resolution combined GGMs were used. The satellite-only GGMs were mainly developed using data from GRACE and GOCE missions, whilst combined GGMs were developed using gravity data from dedicated gravity satellites missions in combination with complementary data such as altimetry and terrestrial gravity data. They are available for the public use at the

International Centre for Global Earth Models (ICGEMs)[3]. The basic and most important information concerning those GGMs can be found on the header information of GGM files and in the associated files from the ICGEM. The main characteristics of those GGMs are summarized in Table 1.

It should be noted that the tide system implemented for all data used within this investigation, i.e. GNSS/levelling, gravity disturbance and GGMs, is a tide-free system which the direct and indirect effects of the Sun and Moon are removed.

3. Methodology

The gravity disturbances δg and height anomalies ζ at point $P(\varphi, \lambda, r)$ are obtained from GGMs as follows (Torge and Müller, 2012)

$$\delta g(\varphi,\lambda,r) = \frac{GM}{r^2}\sum_{n=2}^{\infty}(n+1)\left(\frac{a}{r}\right)^n \sum_{m=-n}^{n}\bar{R}_{nm}\bar{Y}_{nm}(\varphi,\lambda) \quad (1)$$

$$\zeta(\varphi,\lambda,r) = \zeta_0 \frac{GM}{r\gamma}\sum_{n=2}^{\infty}\left(\frac{a}{r}\right)^n \sum_{m=-n}^{n}\bar{R}_{nm}\bar{Y}_{nm}(\varphi,\lambda) \quad (2)$$

with

$$\bar{R}_{nm} = \begin{cases} \Delta\bar{C}_{nm} & m \geq 0 \\ \Delta\bar{S}_{n|m|} & m < 0 \end{cases} \quad (3)$$

and

$$\bar{Y}_{nm} = \begin{cases} \bar{P}_{nm}(\sin\varphi)\cos(m\lambda) & m \geq 0 \\ \bar{P}_{nm}(\sin\varphi)\sin(|m|\lambda) & m < 0 \end{cases} \quad (4)$$

where r is the distance to the geocentre, φ and λ are the geodetic latitude and longitude of the computation point P, respectively, GM is the product of the Newtonian gravitational constant G and the Earth's mass M, a is the semi-major axis of the reference ellipsoid, $\bar{P}_{nm}$ is the fully normalised associated Legendre function of degree n and order m, $\Delta\bar{C}$ and $\Delta\bar{S}_{n|m|}$ are fully normalised spherical harmonic coefficients of the disturbing gravitational potential, being defined as differences between the actual and the normal gravity potential (Torge and Müller, 2012), ζ_0 denotes the zero-degree term (Heiskanen and Moritz, 1967; Ch. 2; Eq. 2-182) and γ is the normal gravity referred to the point P at the physical surface of the Earth.

The differences between gravity disturbances $\Delta\delta g_{(\text{Comb})}$ and quasigeoid heights $\Delta\zeta_{(\text{Comb})}$ are obtained as follows:

$$\Delta\delta g_{(\text{Comb})} = \delta g_{(\text{Comb})}\Big|_{n=2}^{N_{\max}} - \delta g^{(\text{Terr.})} \quad (5)$$

$$\Delta\zeta_{(\text{Comb})} = \zeta_{(\text{Comb})}\Big|_{n=2}^{N_{\max}} - \zeta^{(\text{GNSS/lev.})} \quad (6)$$

where $\delta g^{(\text{Terr.})}$ presents terrestrial gravity disturbances, $\zeta^{(\text{GNSS/lev.})}$ is a quasigeoid height obtained from GNSS/levelling data, $N_{\max}$ is the maximum d/o of the combined GGMs investigated, $\delta g_{(\text{Comb})}$ and $\zeta_{(\text{Comb})}$ present gravity disturbances and quasigeoid heights, respectively, obtained from the combined GGM.

For the satellite-only GGMs, the differences of gravity disturbances $\Delta\delta g_{(\text{Sat})}$ and $\Delta\delta g_{(\text{Sat+EGM2008})}$ as well as the differences of quasigeoid heights $\Delta\zeta_{(\text{Sat})}$ and $\Delta\zeta_{(\text{Sat+EGM2008})}$ are calculated using the following equations :

$$\Delta\delta g_{(\text{Sat})} = \delta g_{(\text{Sat})}\Big|_{n=2}^{l_{\max}} - \delta g^{(\text{Terr.})} \quad (7)$$

$$\Delta\delta g_{(\text{Sat+EGM2008})} = \delta g_{(\text{Sat})}\Big|_{n=2}^{l_{\max}} + \delta g_{(\text{EGM2008})}\Big|_{l_{\max}+1}^{2190} - \delta g^{(\text{Terr.})} \quad (8)$$

$$\Delta\zeta_{(\text{Sat})} = \zeta_{(\text{Sat})}\Big|_{n=2}^{l_{\max}} - \zeta^{(\text{GNSS/lev.})} \quad (9)$$

$$\Delta\zeta_{(\text{Sat+EGM2008})} = \zeta_{(\text{Sat})}\Big|_{n=2}^{l_{\max}} + \zeta_{(\text{EGM2008})}\Big|_{l_{\max}+1}^{2190} - \zeta^{(\text{GNSS/lev.})} \quad (10)$$

where $l_{\max}$ is the applied maximum d/o, $\delta g_{(\text{Sat})}$ and $\zeta_{(\text{Sat})}$ present gravity disturbances and height anomalies, respectively, obtained from the satellite-only GGMs and $\delta g_{(\text{EGM2008})}$ and $\zeta_{(\text{EGM2008})}$ denote the omitted gravity signals of disturbances and height anomalies, respectively, obtained with the use of the EGM2008 up to its maximum degree.

4. Results and analysis

On the basis of the methodology described in Section 3, the GGMs (identified in Table 1) were evaluated across the region of Ethiopia and Uganda using airborne gravity disturbances and GNSS/levelling data, specified in Section 2 (see Fig. 1). The results of this evaluation are presented and discussed in Sections 4.1 and 4.2.

[3] http://icgem.gfzpotsdam.de/ICGEM/

4.1. Evaluation of GGMs over the area of Ethiopia

The differences between gravity disturbances $\Delta\delta g_{(Comb)}$ (cf. Eq. 5) obtained from airborne and terrestrial gravity data available in Ethiopia (see Fig.1) and combined GGMs are depicted in Figure 2. The statistics of these differences are given in Table 2. Figures 3 and 4 show standard deviations of the differences $\Delta\delta g_{(Sat)}$ and $\Delta\delta g_{(Sat+EGM2008)}$ between gravity disturbances obtained from terrestrial data and the corresponding ones obtained from GOCE-based GGMs truncated at the spectral (i.e. l_{max}) range of 100 to 330 d/o with 10 d/o step using Eqs. (7) and (8), respectively. The statistics of $\Delta\delta g_{(Sat)}$ and $\Delta\delta g_{(Sat+EGM2008)}$ at 200 d/o that corresponds to the objective of GOCE satellite mission in terms of spatial resolution, are given in Table 3.

Table 2. Statistics of differences $\Delta\delta g_{(Comb)}$ for Ethiopia [mGal]

GGMs	N_{max}	Min	Max	Mean	Std
EGM2008	2190	–20.32	13.98	0.02	3.90
EIGEN-6C4	2190	–12.33	12.06	0.29	2.30
GECO	2190	–15.98	15.24	0.23	2.98
SGG-UGM-1	2159	–11.31	12.00	0.23	2.39

The results presented in Table 2 and Figure 2 indicate that the fit of combined GGMs investigated to terrestrial gravity data in Ethiopia, in terms of standard deviations of $\Delta\delta g_{(Comb)}$, ranges from 2.3 to 3.9 mGal. They also reveal a remarkable improvement in the combined GGMs developed with the use of GOCE data, i.e. EIGEN-6C4, GECO and SGG-UGM-1, compared to the one that does not include data GOCE satellite mission, i.e. the EGM2008.

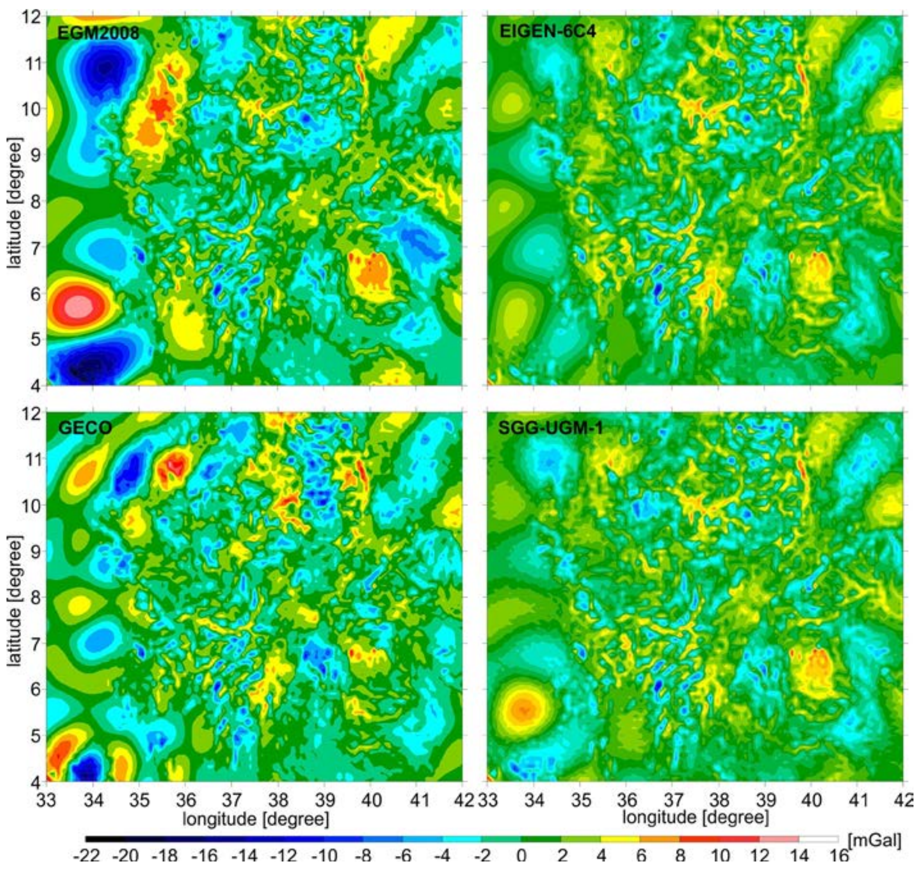

Fig. 2. Differences between gravity disturbances for Ethiopia obtained from airborne and terrestrial data and the corresponding ones determined from combined GGMs

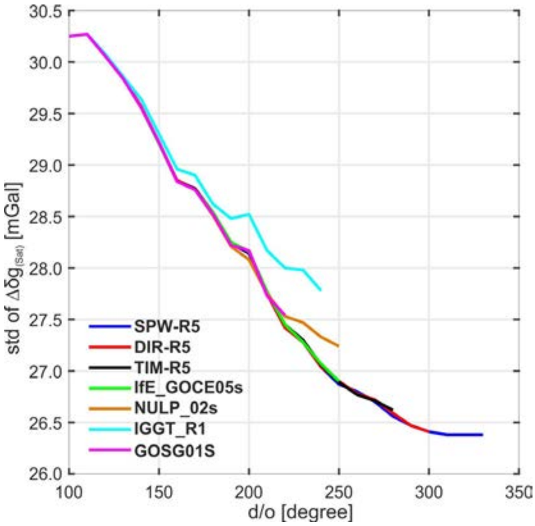

Fig. 3. Standard deviations of differences $\Delta\delta g_{(Sat)}$ for Ethiopia

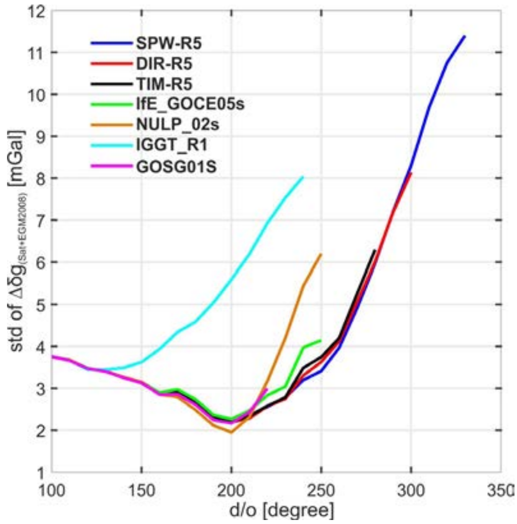

Fig. 4. Standard deviations of differences $\Delta\delta g_{(Sat+EGM2008)}$ for Ethiopia

This improvement reach ca. 40% in terms of standard deviations of $\Delta\delta g_{(Comb)}$, and it is particularly observed in the western areas and some areas in the centre of Ethiopia. This may reveal that for these areas, long wavelengths, e.g. from d/o 2 to d/o 200, components of the Earth gravity field were poorly modelled when developing the EGM2008. The results presented in Table 2 and Figure 2 also exhibit that the EIGEN-6C4 GGM is more accurate compared to the other investigated combined GGMs.

The results presented in Figures 3 and 4 as well as Table 3 illustrate that satellite-only GGMs (investigated in this study) provide consistent results. The only exception is the IGGT_R1 GGM that includes two months of GOCE satellite mission data (see Table 1). The results obtained also reveal that gravity disturbance can be determined with an accuracy of ca. 30 mGal at d/o 100, ca. 28 mGal at d/o 200 and ca. 26 mGal at d/o 330, in terms of standard deviations (STD) of $\Delta\delta g_{(Sat)}$ using satellite–only GGMs based on satellite only data. When compensating the omitted gravity signal, i.e. δg from d/o l_{max} to d/o 2190, using the EGM2008 the fit of satellite-only GGMs investigated, except the IGG_R1 GGM, to terrestrial gravity data in Ethiopia, in terms of STD of $\Delta\delta g_{(Sat+EGM2008)}$, becomes ~2 mGal at d/o 200. From d/o 200 and onward STD of $\Delta\delta g_{(Sat+EGM2008)}$ grow rabidly. This can be ascribed to the strong noise that dominated gravity signal measured by DGSMs in higher spectral bands.

Table 3. Statistics of differences between gravity disturbances for Ethiopia obtained from terrestrial data/airborne gravity survey and the corresponding ones determined from GOCE-based GGMs truncated at d/o 200 [mGal]

GGMs	$\Delta\delta g_{(Sat)}$				$\Delta\delta g_{(Sat+EGM2008)}$			
	Min	Max	Mean	Std	Min	Max	Mean	Std
SPW-R5	–109.72	158.84	–2.05	28.14	–10.41	10.12	0.28	2.18
DIR-R5	–109.78	158.82	–2.05	28.16	–10.42	9.94	0.28	2.19
TIM-R5	–110.44	158.81	–2.21	28.15	–10.44	10.20	0.12	2.20
IfE_GOCE05s	–111.05	157.99	–2.18	28.16	–11.25	10.64	0.15	2.26
NULP_02s	–109.57	160.09	–2.23	28.08	–10.11	10.07	0.10	1.95
IGGT_R1	–115.50	156.94	–2.33	28.52	–27.49	22.96	0.00	5.60
GOSG01S	–110.31	160.02	–2.18	28.17	–10.29	10.42	0.15	2.17

4.2 Evaluation of GGMs over the area of Uganda

The statistics of quasigeoid heights differences $\Delta\zeta_{(Comb)}$ (cf. Eq. 6) obtained from GNSS/levelling data available in Uganda (see Fig. 1) and the corresponding ones from combined GGMs are given in Table 4. Differences $\Delta\zeta_{(Sat)}$ and $\Delta\zeta_{(Sat+EGM2008)}$ (cf. Eqs. (9), (10)) between quasigeoid heights from GNSS/levelling data and satellite-only GGMs were obtained at maximum d/o l_{max} from 100 to 280 with 10 d/o step and illustrated in Figures 5 and 6. The statistics of $\zeta_{(Sat)}$ and $\Delta\zeta_{(Sat+EGM2008)}$ are given in Table 5.

Table 4. Statistics of differences $\Delta\zeta_{(Comb)}$ for Uganda [m]

GGMs	N_{max}	Min	Max	Mean	Std
EGM2008	2190	–0.345	0.378	–0.045	0.270
EIGEN-6C4	2190	–0.268	0.143	–0.147	0.146
GECO	2190	–0.239	0.106	–0.120	0.154
SGG-UGM-1	2159	–0.282	0.123	–0.159	0.136

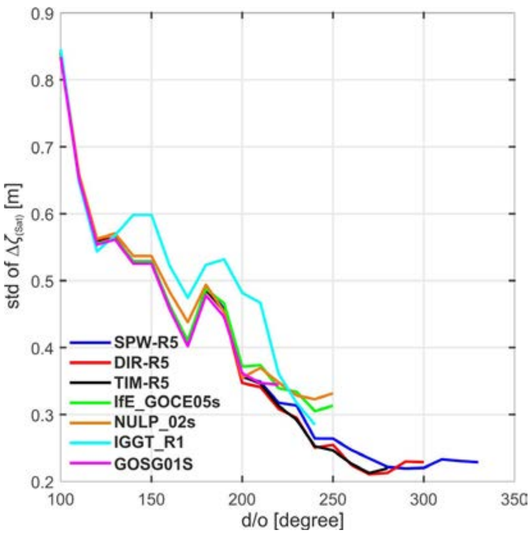

Fig. 5. Standard deviations of differences $\Delta\zeta_{(Sat)}$ for Uganda

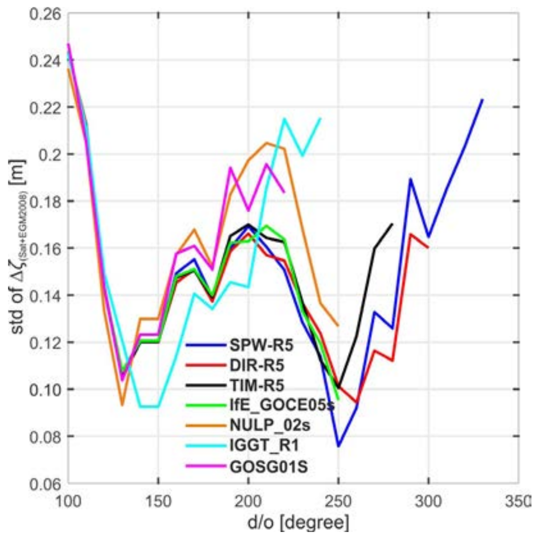

Fig. 6. Standard deviations of differences $\Delta\zeta_{(Sat+EGM2008)}$ for Uganda

When compared to GNSS/levelling data, combined GGMs developed with the use of GOCE satellite mission data showed a clear improvement in the fit (ca. 50%) in the contrary to those that do not include GOCE satellite data, i.e. the EGM2008. In terms of standard deviations of $\Delta\zeta_{(Comb)}$, the esti-

Table 5. Statistics of differences between geoid heights for Uganda obtained from GNSS/levelling data and the corresponding ones determined from satellite-only GGMs truncated at d/o 200 [m]

GGMs	$\Delta\zeta_{(Sat)}$				$\Delta\zeta_{(Sat+EGM2008)}$			
	Min	Max	Mean	Std	Min	Max	Mean	Std
SPW-R5	–0.653	0.402	–0.019	0.356	–0.305	0.189	–0.136	0.169
DIR-R5	–0.637	0.383	–0.017	0.347	–0.279	0.205	–0.133	0.166
TIM-R5	–0.653	0.414	–0.020	0.357	–0.300	0.189	–0.137	0.170
IfE_GOCE05s	–0.703	0.459	–0.025	0.372	–0.286	0.139	–0.142	0.163
NULP_02s	–0.667	0.464	–0.039	0.355	–0.328	0.175	–0.155	0.197
IGGT_R1	–0.926	0.563	–0.021	0.482	–0.324	0.109	–0.137	0.143
GOSG01S	–0.673	0.406	–0.031	0.362	–0.328	0.169	–0.147	0.176

mated accuracy of combined GGMs developed using GOCE satellite mission data is at the level of 14 cm.

The results presented in Figures 5 and 6 as well as Table 5 indicate that the accuracy of quasigeoid heights from satellite-only GGMs reaches the level of 21 cm at higher spectral bands, e.g. d/o 270. When compensating quasigeoid heights signal beyond l_{max} using the EGM2008, their accuracy can reach 14.3 cm and 7.7 cm at d/o 200 and d/o 250, respectively. Figure 6 also illustrates that standard deviations of $\Delta\zeta_{(Sat+EGM2008)}$ at the spectral band from d/o 100 to d/o 330 are randomly changing within the range from ~8 cm to ~24 cm. The main reason of the uneven pattern presented in Figure 6 might be ascribed to the insufficient accuracy of the EGM2008 that has been used to compensate the omitted quasigeoid heights signal at the GNSS/levelling sites.

5. Conclusions

Gravity disturbances and quasigeoid heights obtained from recent four combined global geopotential models (GGMs) and seven satellite-only GGMs were evaluated using the corresponding functionals computed from airborne/terrestrial data restricted to the regions of Ethiopia and Uganda. Moreover, the contribution of dedicated satellite gravity missions to the modelling of the Earth's gravity field over these areas was assessed.

The results obtained reveal a good agreement between gravity disturbances obtained from recent combined GGMs and airborne/terrestrial gravity disturbances data in Ethiopia. This agreement can reach ca. ±2.3 mGal, what takes place in the case of the EIGEN-6C4. The comparison of gravity disturbances obtained from satellite-only GGMs with the corresponding ones obtained from airborne/terrestrial data indicates that satellite-only GGMs provide gravity disturbances with an accuracy level of 26 mGal at d/o 300. When compensating the omitted gravity disturbance signal using the EGM2008, the accuracy of satellite-only GGMs truncated at d/o 200 becomes almost equal to the accuracy of combined GGMs.

The comparison of quasigeoid heights obtained from recent GGMs with the corresponding ones obtained from GNSS/levelling data in Uganda indicates a clear improvement from the EGM2008 to combined GGMs developed with the use of GOCE gravimetric satellite mission data. The standard deviations of the differences between quasigeoid heights being compared decrease from ca. 27 cm to ca. 14 cm. The results of the comparison also exhibit that satellite-only GGMs can be used to determine quasigeoid heights with an accuracy of ~21 cm, which is by 22% (~6 cm) more accurate than the one determined from the EGM2008. When compensating the omitted quasigeoid height signal using the EGM2008, the accuracy of quasigeoid heights obtained from satellite-only GGMs reaches 7.7 cm. The results obtained also reveal that quasigeoid height signal beyond the truncated d/o of satellite-only GGMs, i.e. from l_{max} and onward, is dominated by the error included in the EGM2008.

Overall, the results obtained reveal substantial improvements in GGMs developed with the use of GOCE satellite mission data compared to GGMs that do not include GOCE data, e.g. the EGM2008. In the area of Ethiopia and Uganda, these improvements reach ca. 40% and ca. 50%, respectively. This may reflect and confirm the contribution from DGSMs to improve the modelling of the Earth gravity field over East Africa.

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Udział grawimetrycznych misji satelitarnych w modelowaniu ziemskiego pola siły ciężkości – badanie dla obszaru Etiopii i Ugandy w Afryce Wschodniej

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Streszczenie: Od pierwszej dekady obecnego tysiąclecia do poprawy modelowania pola siły ciężkości Ziemi oraz jego zmian w czasie przyczyniły się ogromnie trzy grawimetryczne misje satelitarne: CHAMP (Challenging Minisatellite Payload), GRACE (Gravity Recovery and Climate Experiment) oraz GOCE (Gravity field and steady-state Ocean Circulation Explorer). Ponadto w maju 2018 roku zostały wystrzelone satelity misji GRACE-FO (GRACE Follow-On) kontynuującej dostarczanie danych pomiarowych otrzymywanych z misji GRACE. Na podstawie tych danych są stale opracowywane globalne modele geopotencjału. Głównym celem podjętych w niniejszej pracy badań jest ocena wygenerowanych w ostatnich kilku latach globalnych modeli geopotencjału oraz oszacowanie wpływu grawimetrycznych misji satelitarnych na modelowanie pola siły ciężkości Ziemi dla obszaru Etiopii i Ugandy w Afryce Wschodniej. Z globalnych modeli geopotencjału opracowanych na podstawie danych z grawimetrycznych misji satelitarnych, wyznaczono funkcjonały pola siły ciężkości, tj. zakłócenie grawimetryczne i wysokość quasigeoidy, a następnie porównano je z dostępnymi lotniczymi/naziemnymi danymi grawimetrycznymi dla obszaru Etiopii oraz danymi satelitarno-niwelacyjnymi dla obszaru Ugandy. Uzyskane wyniki poddano analizie i dyskusji. Zaobserwowano poprawę dokładności modelowanego ziemskiego pola siły ciężkości o ok. 40–50% w przypadku wykorzystania globalnych modeli geopotencjału opracowanych z użyciem danych z misji satelitarnej GOCE.

Słowa kluczowe: Afryka Wschodnia, globalne modele geopotencjału, funkcjonały pola siły ciężkości, grawimetryczne misje satelitarne