Validations of Three Global Gravity Field Models Using the QDaedalus System Observed Astrogeodetic Vertical Deflections in the Munich Region, Germany

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1 Introduction

Currently, astrogeodetic vertical deflections (VDs) are determined with the Digital Zenith Camera System (DZCS) or the QDaedalus system.

In this study, we used the QDaedalus system in the Munich region to assess the quality of three global gravity field models—Global Gravitation Model Plus (GGMplus), Earth Residual Terrain Modelled 2160 (ERTM2160) and Earth Gravitational Model 2008 (EGM2008)—through comparison with the QDaedalus observations.

This vPICO presents the results of these comparisons between the predicted and observed VD data. We also compare the results of the Munich Region study with a prior QDaedalus study conducted in Istanbul (Albayrak et al. 2020a) to assess the accuracy of the EGM2008 and GGMplus models.

2 The QDaedalus System

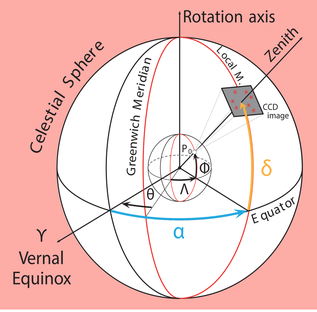


▶The QDaedalus system was developed by ETH Zurich in 2014 (Guillaume et al., 2015) for use in nighttime astrogeodetic and daytime geodetic observations.

▶**The QDaedalus observation steps**
1. Installation of the QDaedalus system
2. CCD camera calibration
3. Orientation to reference star (e.g. Polaris)

▶More information about QDaedalus can be found in Guillaume et al. (2015), Hauk et al. (2017) and Albayrak et al. (2020a).

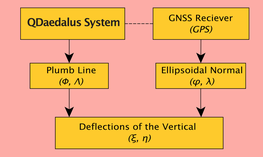
3 Astrogeodetic Measurement Technique



Star Located at Zenith

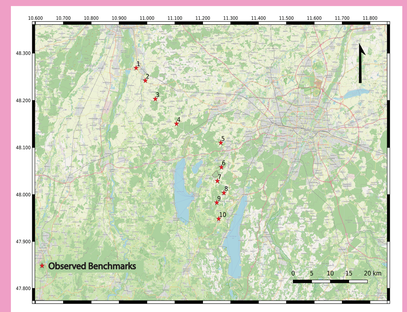
$\Phi = \delta \quad \Lambda = \alpha - GAST$
$\theta = GAST$

$\Phi = \delta_z$ (catalog, ERP, x, y, model, refraction) + μ_Φ
$\Lambda = \alpha_z$ (catalog, ERP, x, y, model, refraction) + μ_Λ - GAST (t_{GPS}, ERP)



$\xi = \Phi - \varphi$
$\eta = (\Lambda - \lambda) \cos \varphi$
$\varepsilon = \sqrt{\xi^2 + \eta^2}$

4 Astrogeodetic Observations in the Munich Region



▶The Munich region profile was established with 10 benchmarks (BMs) from existing high-quality VDs from Hannover DZCS.

▶3-4 QDaedalus observation series (approx. 15 min each) completed per session at the BM (weather dependent).

▶The precision and accuracy of the QDaedalus determined to be ~0.2″ for both the N-S and E-W components (Albayrak et al. 2020a).

5 Global Gravity Field Models- GGMplus, ERTM2160 and EGM2008

The observed astrogeodetic VDs data are independent data. 10 benchmark observations in the Munich region were used to assess the quality of three global gravity field models:

1. Global Gravity Model Plus (GGMplus; Hirt et al. 2013): based on satellite (GRACE, GOCE) gravity data, and EGM2008 terrestrial and altimetry-derived marine gravity observations, and topography-inferred synthetic gravity information at shorter spatial scales.

2. Earth Residual Terrain Modelled 2160 (ERTM2160; Hirt et al. 2014): created in the context of the GGMplus initiative to deliver the short-scale constituents for the GGMplus gravity maps.

3. Earth Gravitational Model 2008 (EGM2008; Pavlis et al. 2012): used here directly, and indirectly via the GGMplus. The EGM2008 model was developed using multi-mission radar altimetry-derived gravity anomalies over ocean areas.

6 VDs comparison in the Munich Region

▶The three models' predicted VDs were compared with the QDaedalus observed VDs. The results of these comparisons between the observed and predicted VD data are [all units are arcseconds]:

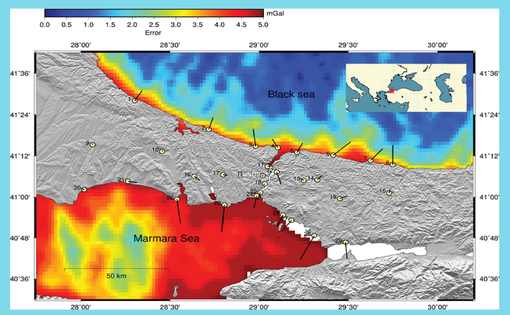
	QDaedalus-GGMplus		QDaedalus-EGM2008		QDaedalus-ERTM2160	
BM No	N-S	E-W	N-S	E-W	N-S	E-W
1	-0.14	0.01	-0.42	0.11	-0.26	0.13
2	-0.04	-0.18	-0.38	0.14	-0.32	-0.20
3	0.27	-0.33	0.04	-0.34	-0.31	-0.17
4	0.29	0.27	0.55	0.11	-0.05	0.22
5	-0.15	-0.19	-0.77	-0.30	-0.18	0.07
6	0.00	-0.23	0.13	-0.71	-0.35	-0.08
7	0.13	0.27	0.79	0.46	-0.36	0.17
8	-0.27	0.12	-0.44	1.13	-0.62	-0.02
9	-0.05	0.39	-0.02	1.78	-0.24	0.30
10	0.16	0.24	0.86	1.53	0.26	0.19

(i) The GGMplus predicted VD values were found to be closer to the observed VDs, with the differences for both the N-S and E-W VD components being ~0.2″, reaching a maximum of 0.3″ and 0.4″ for the N-S and E-W components, respectively;

(ii) The ERTM2160 predicted values were also found to be closer to the observed VDs, with differences of 0.4″ or less for the N-S component, with the exception of one benchmark (BM 8), and 0.2″ or less for the E-W component, with the exception of one benchmark (BM 9);

(iii) When the predicted VDs computed using EGM2008 were analysed, we found that they were less accurate than the predicted GGMplus and ERTM2160 values. Therefore, the maximum differences between the observed and EGM2008 predicted VD data were 0.9″ for N-S and 1.8″ for E-W.

7 VDs Comparison in Istanbul



The VDs residual map obtained though observed and calculated VDs. The Danish National Space Center (DNSC) data set is accompanied by an accuracy map reflecting the spatially varying gravity anomaly errors (Albayrak 2020).

▶ The 30 selected BMs: 21 BMs located in coastal zones and remaining 9 BMs in the interior zone. The standard deviations (SDs) for all observations are ~0.2″ for both components.

▶At all sites we used VDs from the GGMplus and EGM2008 for comparisons with the QDaedalus observations. This comparison indicates that the differences tend to be increased at the coastlines.

▶At 15 stations, the N-S components exhibited large differences ranging between 2″ and 6″. These 15 stations are located along the coastal areas. There were 3 stations with differences of more than 2″ for the E-W components. These locations (BMs 6, 7 and 28) on the coast also had the N-S component differences of more than 2″.

8 Conclusions

▶In this study, the VD data observed in Munich was used to control the quality of the GGMplus, ERTM2160 and EGM2008 global gravity field models.

▶We found that the VD data predicted by the three models gave results close to the VD data observed via QDaedalus, but GGMplus and ERTM2160 were more accurate than EGM2008, since they are a combined model that also includes EGM2008 gravity data.

▶We also conducted QDaedalus observations in Istanbul in 2018, and compared the observed VDs with GGMplus and EGM2008.

▶The SDs for the observed VDs in the Munich Region and Istanbul is ~0.2″ for both the N-S and E-W components.

▶The results of the interior zone of Istanbul is similar to the results of the Munich Region, but the results in the coastal areas of Istanbul have low accuracy due to weaknesses of the EGM2008 satellite radar altimeter data (see also Albayrak et al. 2020).

▶As a result, it was concluded that the quality of the VDs predicted with the GGMplus was better than EGM2008 in both the Munich region and the coastal and interior zones of Istanbul.

▶These studies show that the quality of the existing and future global gravity field models can be assessed with data observed with the QDaedalus system.

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