Gravimetry and geoid modelling in Croatia—
an overview

Loránd Eötvös centenary

Matej Varga, Tomislav Bašić

in Budapest, May 15th, 2019
Eötvös’s influence on gravity and magnetic field research in Croatia

Szabó 2016
Artur Gavazzi- the pioneer of gravimetry in Croatia

Bio

- Split, 1861 - Zagreb, 1944
- mainly physical geographer, but contributed to hidrology, meteorology, oceanography, geodesy
- dean of the Faculty of Philosophy (Ljubljana)
- member of several academies in Europe
- wrote several books

Figure 1: prof. dr. Artur Franović Gavazzi (Hanžek et al. 2012)

Figure 2: Constants of the Gavazzi’s variometer
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Eötvös torsion balance

- supported and financed by Croatians: prof. dr. Karlo Gorjanović-Kramberger, ban Pavao Rauch
- built during 1909 and 1910
- Hungarians worked on instrument: Ferdinand Süss (1848–1921), Dezső Pekár (1873–1953), István Rybár (1886-1971)
- for that time-period the most accurate Eötvös torsion balance instruments (∼ 1 E)

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Measurements

- in 1911 and 1912 performed torsion balance measurements- one of the first gravity field measurements across Croatia
- made topographic reductions
- Gavazzi communicated intensively with Eötvös, e.g. "Equations, by which we perform calculations were published, but Eötvös did write to me some significant changes which simplified our calculations..."
- in 2013 published results of 51 measurements of 37 different sites (Gavazzi 1913)
Boris Apsen- outstanding mathematician

Bio

- Moscow, 1894 - Split, 1980
- immigrated from Russia to former Yugoslavia in 1921
- in 1916 graduated law and economics
- in 1931 graduated geodesy at the Faculty of Geodesy
- in 1942 obtained PhD degree with thesis Eötvös' gravitational variometer and his theory and application in higher geodesy
- the first doctor of geodetic sciences at the Technical Faculty (former) of University of Zagreb
- worked as mathematics teacher on university and high-schools
- wrote several books in (higher) mathematics which are still considered valuable source of knowledge in faculty education in Croatia

Figure 3: Boris Apsen (Frančula 2007)
Torsion balance from the Faculty of Geodesy

Was used in research, industry and education during second half of the 20th century

Professors of physical geodesy:

- prof. dr. Nikola Čubranić, 1905-1989
- prof. emer. dr. Stjepan Klak, 1920-2000
- academic prof. dr. Krešimir Čolić, 1938-2000
- prof. dr. Tomislav Bašić
- since ~2000 held in Technical Museum Nikola Tesla (Zagreb)

Figure 4: Schematic diagram of the horizontal variometer (large double balance Eötvös torsion balance) which was held on the Faculty of Geodesy, Univ. of Zagreb
"From 1902 to 1904, R. Eötvös measured all three rectangular components of the geomagnetic field at Fruška gora and further to the north, but these data were never released. Following gravity variation measurements during 1911 and 1912 in Srijem, Gavazzi calculated magnetic declination at 51 points using his own and previous Eötvös data along with time variation registrations in Pula.” (Brkić et al. 2003)
Gravity field research in Croatia was strongly influenced by Loránd Eötvös.

"I cannot finish writing this part of the book if I do not thank mr. prof. dr. baron Eötvös and his associates dr. D. Pekar and dr. Stj. Rybár, who happily helped me on the Physical Institute in Budapest.” (Gavazzi 1913)
Gravimetry, geoid modelling and geomagnetism in Croatia—current status
Study area

Figure 6: Topography of the Republic of Croatia
Figure 7: Stations of the Croatian Fundamental Gravity Network (Bašić et al. 2006, Markovinović 2009)

Description

- gravity reference system: IGSN71
- 0. order: 6 points (1996-2000)
- 2nd: 193 points (2010-2015), adjustment in progress
- horizontal gravimetric calibration base, in progress
Gravity database

Figure 8: Distribution of the points in the database

Description

- ~28,000 points (~1pt/18 km²)
- measurements from 1970s to 1995
- database was several times updated, de-biased, cleaned
- estimated accuracy: $\sigma_{pos} = \pm 0.3$ m, $\sigma_H = \pm 0.5m$, $\sigma_{\Delta g} = 2 - 4$ mGal
Maps of gravity anomalies - recent updates

(a) Map of free-air gravity anomalies

(b) Map of gravimetric terrain corrections

(c) Map of complete Bouguer anomalies

(d) Map of Airy-Heiskanen topo-isostatic anomalies
## Quasi-geoid modelling in Croatia

<table>
<thead>
<tr>
<th>Stats and info</th>
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<th>HRG2009</th>
<th>HRG2015</th>
<th>HRG2018</th>
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<td>495</td>
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</table>
HRG2018: latest gravimetric quasi-geoid model

(e) HRG2018 quasi-geoid model

(f) Estimated accuracy
Geomagnetism in Croatia today

Figure 9: Basic Croatian Geomagnetic Network (Brkić et al. 2013)

Description

- more than 200 years of geomagnetism in Croatia
- successful cooperation with Tihany geomagnetic observatory on the project Joint Croatian-Hungarian Geomagnetic Repeat Station Survey (Brkić et al. 2013)
- gravity anomaly maps (Varga 2014)
- recent geomagnetic information models (Brkić 2019)
- project in progress: 2nd Geomagnetic Information Renewal Cycle (Brkić et al. 2018)
## Future ideas

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<tr>
<td>-</td>
<td>absolute gravity re-observations</td>
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<td>re-adjust all orders of gravimetric networks</td>
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<td>densify terrestrial gravity database</td>
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<td>shipborne gravimetry</td>
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<td>modernize height reference system</td>
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Thank you!

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References


