Status of the Croatian First Order Gravity Network

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Abstract

Since Croatian Geodetic Institute (CGI) started to work in December 2001 preliminary work regarding measurements of the Croatian First Order Gravity Network has been carried out. The network will be connected to the Croatian Zero Order Gravity Network. For measurements of the Croatian First Order Gravity Network two Scintrex CG-3M gravimeters are prepared: HGI-1 and HGI-2. Their behavior and capabilities are systematically analyzed: drift, temperature compensation, tilt sensor zero adjustment, tilt sensor sensitivity adjustment, tilt sensor cross coupling, battery check and gravimeter clock drift. In this period drifts of the both gravimeters become more linear, and that is improvement of the main gravimeter characteristic. To analyze structure of a gravimeter signal in detail, stability of the HGI-2 gravimeter was analyzed using wavelet multiresolution technique. To verify gravimeters in the fieldwork, test measurements were done. Design of the test gravity network contains two absolute gravimetric points. That is giving opportunity for reliable verification of the gravimeters. Gravimeters analysis is showing that they can be used in measurements of the Croatian First Order Gravity Network.

1. Introduction

A project of establishing new Croatian First Order Gravity Network is one of the projects that Croatian State Geodetic Administration (SGA) implemented in a five years plan "State Survey and Real Estate Cadastre" that is supported by Croatian government.

All gravimetric works in Croatia are going to be connected to the Zero Order Gravity Network (see Fig. 1). It was established in the projects: Connection of the Republic of Croatia to international absolute gravity network and UNIfication of GRAvity systems in Central Europe (UNIGRACE). Absolute measurements were done by Bundesamt für Kartographie und Geodäsie (BKG) from Frankfurt am Main (Germany) and Ecole et Observatorie des Sciences de la Terre (EOST) from Strasbourg (France). Zero Order Gravity Network includes six absolute gravity points: Zagreb - Puntijarka, Zagreb - Maksimir, Osijek, Pula, Makarska and Dubrovnik (Čolić et al., 1997; Čolić et al., 2000; Medak et al., 2001a; Medak et al., 2001b; Marjanović, 2002). The new Croatian First Order Gravity Network will be connected to the Croatian Zero Order Gravity Network and data of absolute points are checked and systemized.

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Revision of the Croatian part of former Yugoslavia gravity network, and proposal for new Croatian First Order Gravity network was made by the Faculty of Geodesy University of Zagreb (Bašić et al., 2001, Markovinović, 2001).

The proposal includes design of the new gravity network and national calibration line (see Fig. 1 and 2). The New Croatian First Order Gravity Network includes 36 points on the land, and 15 points should be placed on the islands.

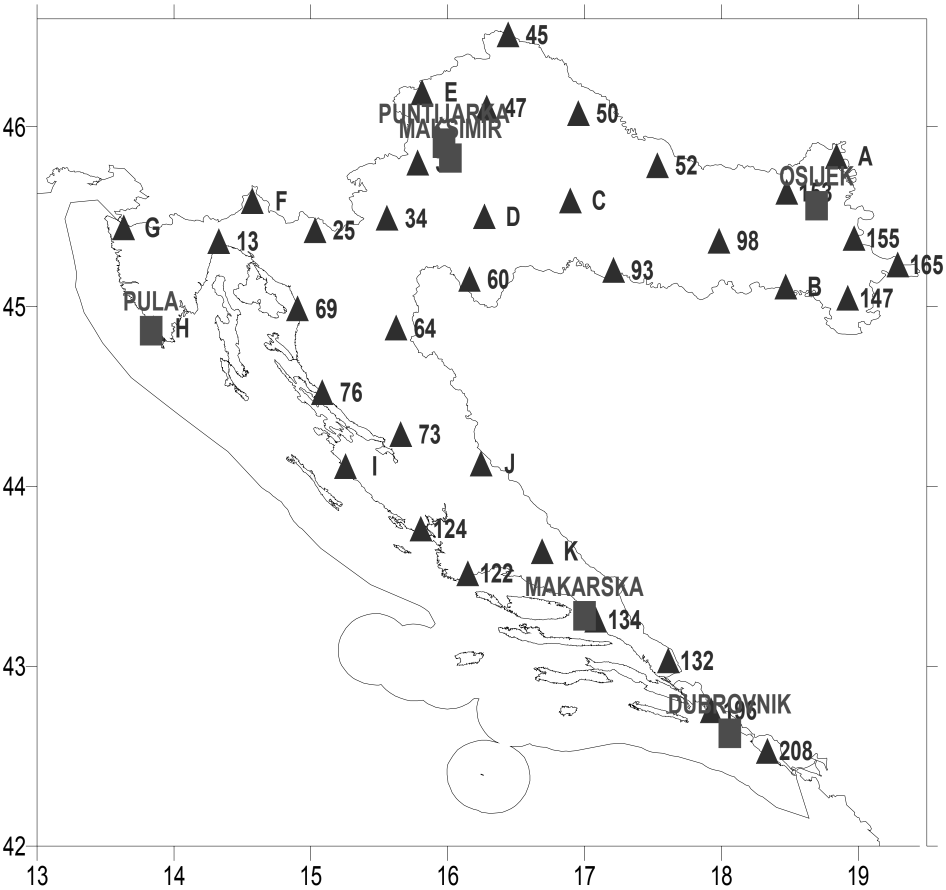

Fig. 1 Croatian Zero (squares) and the First Order Gravity Networks (triangles).

Croatian calibration line consists of 10 points in north-south direction (see Fig. 2). Three points are absolute gravimetric points. The differences in latitude of the first and the last point is ≈ 2° 32' (≈ 270 km) (Markovinović and Rezo, 2002).

Croatian Geodetic Institute (CGI) is a new institution. It started to work in December 2001. In that time Zero Order Gravity Network was already defined and design of the First Order Gravity Network was determined.

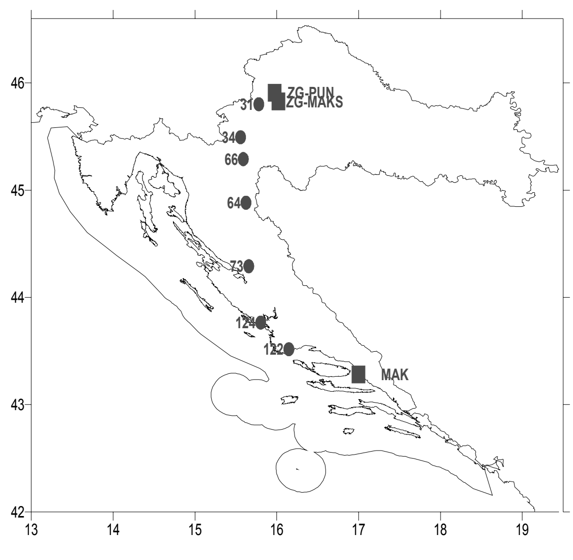

Fig. 2 Croatian calibration line.

2. Gravimeters preparation for measurement of the First Order Gravity Network

After establishment and foundation of the CGI two relative Scintrex CG-3M gravimeters (HGI-1 and HGI-2) were received from SGA. They will be used in measurement of the First Order Gravity Network. Before using the relative gravimeters in measurements of state gravity networks they should be proofed and analyzed. They should satisfy measurement criteria. Considering the problem, extensive work has been done. It includes: gravimeters initial verifying, systematic analysis of gravimeters main characteristics, analysis of measurements system stability and drift, gravimeter testing on the basis of field measurements and calibration.

3. Gravimeters initial checking

During initial verifying of gravimeters HGI-1 and HGI-2 functionality it was discovered that operating systems in both gravimeters had millennium bug. After contacting the gravimeters manufacturer Scintrex, new operating systems were received and replaced in the both gravimeters.

Another delay of using gravimeter HGI-1 was caused by the malfunctioning of temperature sensor. The gravimeter was repaired in Scintrex (Canada).

After repairing it, the same gravimeter experienced reading jumps (tare). The analysis of problem showed that the reading jumps were caused by change of a rate of an artificial, man made, micro seismic in the building where measurements were done (Hećimović, 2002), and reading jumps were not caused by malfunctioning of the gravimeter (Hrvatski geodetski institut, 2002a).

4. Systematic analysis of gravimeters' main characteristics

After solving the initial problems, the gravimeters have been made fully operable. To prepare gravimeters for measurements of the national gravity networks their behavior and capabilities are systematically analyzed. That includes regular checking of: drift, temperature compensation, tilt sensor zero adjustment, tilt sensor sensitivity adjustment, tilt sensor cross coupling, battery check and gravimeter clock drift.
Gravimeters are systematically analyzed in the period of about one year. At the beginning of the analysis period, drifts of both gravimeters were parabolic and at the end of analyzing period, drifts became more linear. Drifts unlinearities in both gravimeters (HGI-1 and HGI-2) can be clearly recognized in a longer continuous measurement (see Fig. 3 and 4).
Parabolic drift of the HGI-1 on the beginning of the analysis period can be clearly recognized in seventeen days continuous measurements (see Fig. 3).

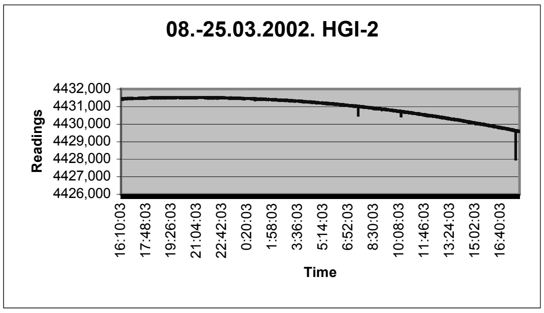

Fig. 3. Readings of the gravimeter HGI-2 at the beginning of the analysis period.

Drift of HGI-2 had become more linear with time and at the end of the analysis period it had much better linearity characteristic (see Fig. 4).

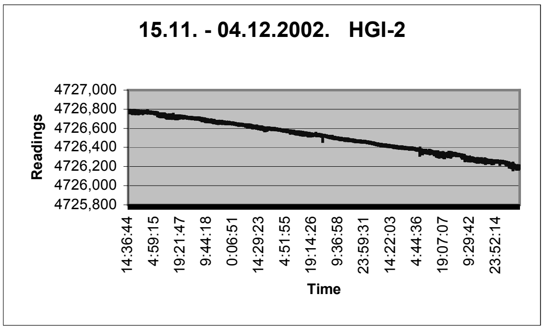

Fig. 4. Readings of the gravimeter HGI-2 at the end of the analysis period.

Parabolic drift of the gravimeter HGI-1 at the beginning of the analysis period can be clearly recognized in two weeks continuous measurements (see Fig. 5).

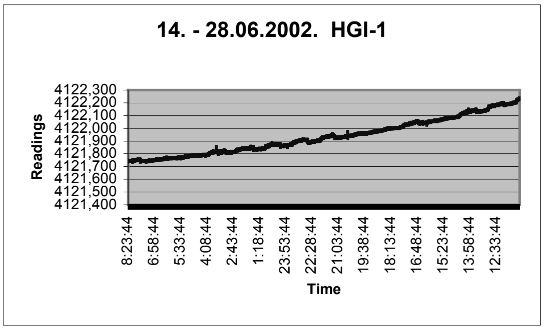

Fig. 5. Readings of the gravimeter HGI-1 at the beginning of the analysis period.

At the end of the analysis period drift of HGI-1 had much better linearity characteristic (see Fig. 6).

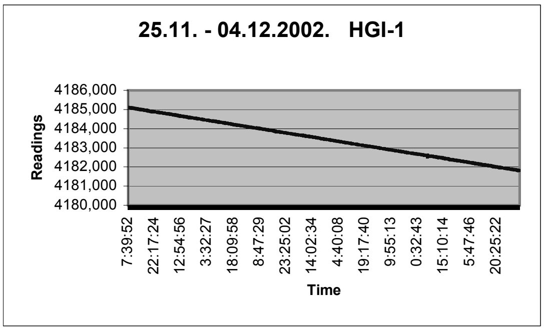

Fig. 6. Readings of the gravimeter HGI-1 at the end of the analysis period.

Drifts are significantly improved in both gravimeters. That is improvements of the main gravimeters characteristic. Other gravimeters characteristics, that are systematically analyzed, are indicating normal behavior of the gravimeters.

5. Analysis of gravimeter measurements system stability

Stability of the measurements system is also one of the main gravimeter characteristics. It has long and short time characteristic.

Long-term stability of gravimeters HGI-1 and HGI-2 is analyzed using drift changes in the period of about one year (see Fig. 7 and 8).

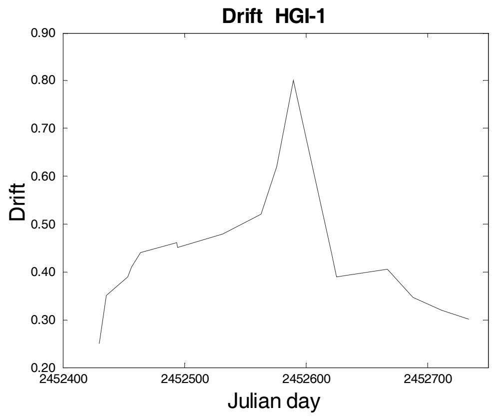

Fig. 7. Drift of HGI-1.

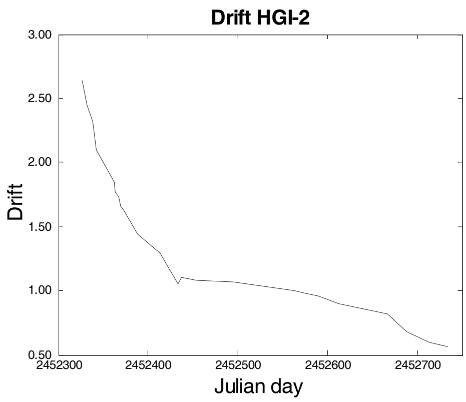

Fig. 8. Drift of HGI-2.

Drift change of the gravimeter HGI-1 is showing irregular behavior, but the amplitudes are significantly smaller than by the gravimeter HGI-2. Drift of the gravimeter HGI-2 has decreasing trend, but drift changes are significantly bigger than by the HGI-1. Drift changes of the HGI-2 are smaller in the second part of analyzing period, and they are showing long time stabilization of the measurements system of HGI-2.

To analyze the short time stability of the measurements system, the signal of the gravimeter HGI-2 was analyzed using wavelet multiresolution technique (Hećimović and Markovinović, 2002). Coifman wavelet (Coiflet) of the fifth order from the family of orthogonal wavelet was used. Coifman wavelet is presented on the Fig. 9 and on the Fig. 10 is associated scaling function.

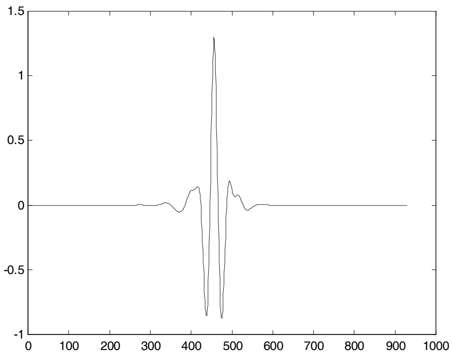

Fig. 9. Coifman wavelet of the 5th order.

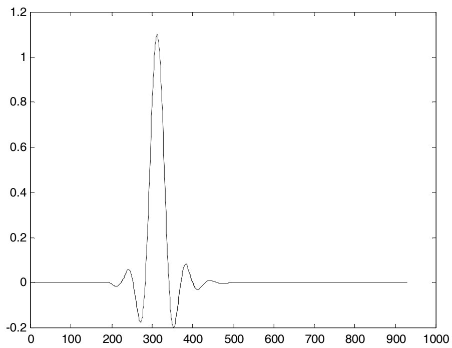

Fig. 10. Associated scaling function.

Multiresolution was made until the third level (see Fig. 11)

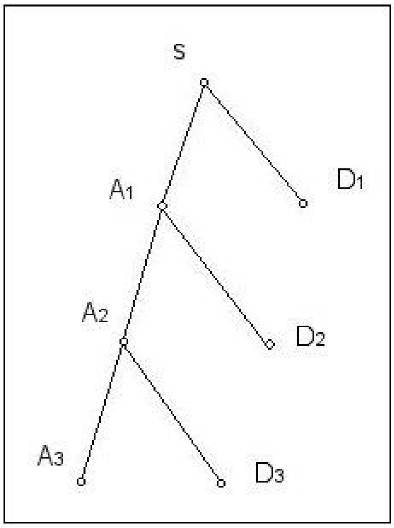

Fig. 11. Wavelet multiresolution decomposition.

Input in wavelet analysis is one-day continuous measurement signal of gravimeter HGI-2 (see Fig. 12). Gravimeter readings are in real time corrected for scaling factor, temperature, "a priori" drift, Earth tides and gravimeter tilt.

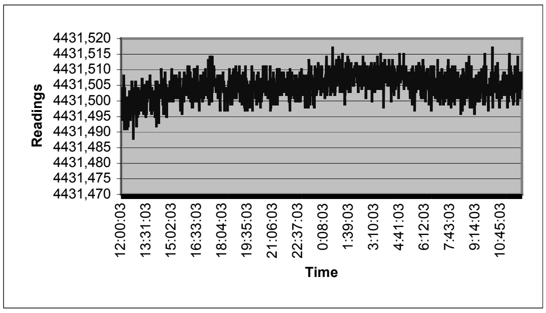

Fig. 12. One-day continuous readings used in wavelet analysis.

Fig. 13 is showing wavelet decomposition of the signal: approximation on the third level (A3) and details on the all three levels (D1, D2 and D3).

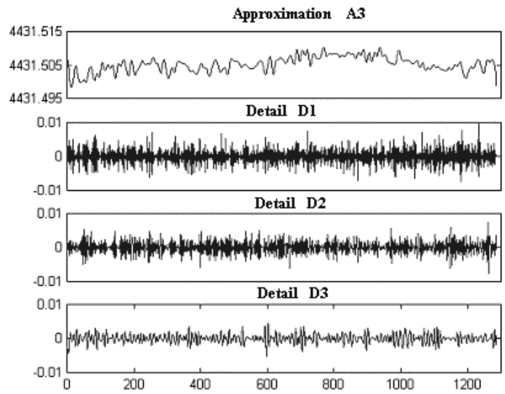

Fig. 13. Approximation A3 and decomposed details D1, D2 and D3.

The approximation is taking trend and the main part of signal energy. It is free of high frequency part. In the approximation A3, the remaining signal of half-day period can be recognized (see Fig. 13). It could be caused by not completely compensated reductions (e.g. Earth tides). Signal disturbances in approximation (A3) are from 10 to 30 minutes long. They are irregular and smaller then $0{,}010 \cdot 10^{-5}$ ms^{-2}. They are most probably caused by longer microseisnmic influences on the measurements.

Details are having the characteristic of the noise. With the higher decomposition level, amount of information in detail is lower and the noise has finer structure. The details are giving insight in the short time instabilities of the measurement system. Amplitude of detail D1 is $0{,}017 \cdot 10^{-5}$ ms^{-2} for D2 is $0{,}015 \cdot 10^{-5}$ ms^{-2} and for D3 is $0{,}009 \cdot 10^{-5}$ ms^{-2}. The detail D1 has period of about one-epoch of measurements (60 seconds), detail D2 has four epochs and detail D3 has little bit less than then epochs. In the table 2 there are the main statistical characteristics of the details given, and on Fig. 14 there are the distributions of the details presented.

Table 2: Main statistical characteristics of the details.

	D1 [10^{-5} ms^{-2}]	D2 [10^{-5} ms^{-2}]	D3 [10^{-5} ms^{-2}]
Min.	-0.0074	-0.0078	-0.0054
Max.	0.0102	0.0073	0.0044
Mean	1.947e-006	4.265e-006	-13.496e-006
StDev.	0.0024	0.0018	0.0012

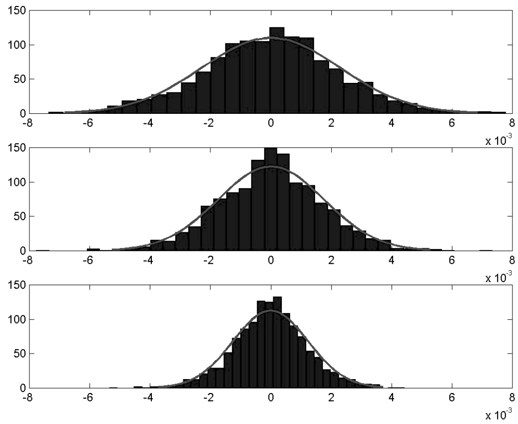

Fig. 14. Distributions of the details D1, D2 and D3.

6. Test measurements

To check gravimeters in the fieldwork, test measurements were done. Design of the test gravity network (see Fig. 15) contains two absolute gravimetric points (1 Zagreb Maksimir and 2 Zagreb Puntijarka).

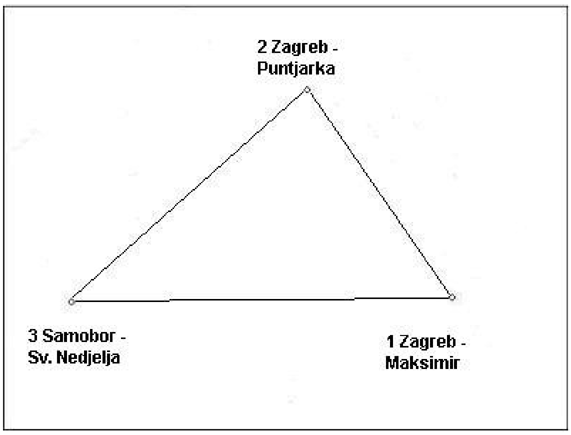

Fig. 15. Gravimetric test network

To collect the data that can be used for reliable checking of the instruments, star method in all three combinations is used.

After measurements reductions and drift corrections a priori closure of figure is $0{,}011 \cdot 10^{-5}$ ms^{-2} for gravimeter HGI-1 and $0{,}013 \cdot 10^{-5}$ ms^{-2} for gravimeter HGI-2. Network datum is defined with two absolute points. After adjustment, the referent standard deviation is $0{,}0096 \cdot 10^{-5}$ ms^{-2}. The new gravity value of the third point has difference in comparison to old Yugoslav gravity network of $14{,}8 \cdot 10^{-5}$ ms^{-2}. That is the difference between datum defined by two absolute gravity points and the old Yugoslav gravity datum (Hrvatski geodetski institut, 2002b). The old Yugoslav gravity datum, that Croatia was a part of, was determined by using the datum point in Belgrade.

7. Gravimeters calibration

Measurements on the two absolute points, that are also a part of the Croatian calibration line, are used for calibration of gravimeters. Gravity difference between the absolute points is $151 \cdot 10^{-5}$ ms^{-2} what is giving opportunity for calibration. Linear calibration coefficient was determined and imported in memory of gravimeter. In that way the gravimeters are in real time scaled considering the Croatian calibration line.

8. Conclusions

Preliminary work for measurements of the Croatian First Order Gravity Network has been done. The analysis of gravimeters HGI-1 and HGI-2 is showing tendency of increasing gravimeter measurements quality and performances. They can be used for measurements of the Croatian national gravity network. All preparations for measurements of the First Order Gravity Network are done. Faculty of Geodesy University of Zagreb will do field measurements. They will start this spring.

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