HRG2009 - New High-resolution geoid for Croatia
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SUMMARY

Regarding to the Earth’s gravity field data used: point free air anomalies, discrete geoid undulations obtained by GPS/leveling on the mainland and by satellite altimetry in the Adriatic Sea, long- and medium-wave field structures taken from the latest detailed global geopotential model (EGM2008), high frequency field structures modeled with the help of 3x3 Shuttle Radar ESM and applying of least squares calculation technique, very accurate geoid surface over the entire territory of the Republic of Croatia was obtained. Based on comparisons with the control GPS/leveling points (not used in calculations), we can say that external (geodetic) accuracy of the final result is very satisfactory to almost the entire land territory and a little worse in the Adriatic Sea (islands), which means significantly more reliable results compared to old survey methods. The obtained geoid surface has been used for different purposes, principally in the precise height definition using modern GNSS technology. Therefore, the Croatian Positioning System - CROPOS was upgraded in 2011 with the new service which enables the real-time transformation of ellipsoid heights to the normal, orthometric heights using HRG2009 model GPS and Triode Transfer/Generator software for more than 440 surveying and geoinformation companies in Croatia.

ANALYSIS

In Table 1 on Fig. 2, the main statistics of gravity anomalies is presented. The effect of the applied remove procedure is evident on decreasing standard deviation, which goes from 29.20 mgal for observed anomalies to 5.49 mgal for residuals (lg9G08h - lgEGM2008 - lgTM). A significant reduction of the mean value from 11.58 mgal to 0.28 mgal (good centered data) can also be recognized (1 mgal = 10^-3 m).

A priori information about the variation of the local field is introduced through the empirical covariance function calculated using 29330 residual gravity anomalies lying on the central Croatia part (used for the empirical covariance function has the value of only 30.03 mgal and the first zero-value occurs already at 9 km distance (covariance graph on Fig. 2).

Table 1. The characteristics of geoid reduction error of 495 GPS/leveling points [m].

<table>
<thead>
<tr>
<th>Type</th>
<th>Mean</th>
<th>St. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>11.58</td>
<td>5.49</td>
<td>0.28</td>
<td>1.91</td>
</tr>
<tr>
<td>residuals</td>
<td>0.28</td>
<td>0.04</td>
<td>0.28</td>
<td>0.35</td>
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</table>

For the purpose of correct absolute orientation of the calculated geoid surface, a significant number (495) of GPS/leveling points distributed across the Croatia has been used. The statistics are presented in Table 1, where an apparent remove effect is present again, but it should be noted that the value of the mean NRES is 1.024 m, most likely originates from the discrepancy between the used EGM2008 model and the definition of normal vertical Datum, which is related to the 1.5 tides gauges.

QUALITY ASSESSMENT

Assessment of HRG2009 quality was done in two ways. Firstly, its accuracy rating was made through comparison with 495 GPS/leveling undulations, used in the computations themselves. It shows that mutual agreement is remarkably high, because the standard deviation of only 2.17 cm and a mean difference of almost zero, pointing primarily to the well-chosen methodology and implementation of computing, and high reliability of the new geoid solution of 2.3 cm over most of the Croatian mainland (Fig. 3).

Table 3. Statistics corresponding to Fig. 6 following differences:

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Mean</th>
<th>St. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRES</td>
<td>0.13</td>
<td>0.01</td>
<td>0.095</td>
<td>0.26</td>
</tr>
<tr>
<td>Max</td>
<td>0.095</td>
<td>0.01</td>
<td>0.26</td>
<td>0.26</td>
</tr>
</tbody>
</table>

After that an external (independent) quality assessment through its comparison with 59 GOCE/leveling control undulations (not used in the computation) was done. This comparison confirms that there was envious absolute accuracy of the new geoid, because the standard deviation of 3.5 cm and mean difference of almost zero, confirming high reliability of this solution (Fig. 3).

Comparison between HRG2009 and EGG2008 geoid model has been done for all points of 30’ grid, within solution area for Croatia, meaning 47°N-46.67°N and 15°E-15.97°E. Comparison for the sea surface difference of 24.3 cm, which is consequently result of different height reference, i.e. Croatian geoid model refers to HRG2012 mean sea level surface, while EGG2008 refers to Amsterdam MSL. Furthermore, standard deviation is 17.0 cm, while varies from minimum of -0.214 m to maximum of 0.452 m (Fig. 4). Greater disagreements can be found out side of croatian border, due to different data used, different methods, as well as border effects.

CONCLUSION

As shown in this study, new local high-resolution geoid solution HRG2009 has been calculated, showing an accuracy of few (2-3) centimeters for predominant part of Croatia, especially on land area. At the same time, regional quasigeoid EGG2008 fits very well at GNSS/leveling points in large part of continental Croatia, varying just 3.5 centimeters, aside to few problematic areas, mostly on border to Monte Negro and Italy, where the differences are above 10 cm.

Due to this facts along with the newest GOCE results, there is a clear need for more precise overlap of European and Croatian geoid model in the forthcoming years. Better fitting new solutions are needed both in regional and local level.

REFERENCES


HRG2009 IMPLEMENTATION

By State Geodetic Administrations’ Decision on determining the official geodetic datum and map projections of Republic of Croatia (8. August 2009) regulations on transfer from old to new geodetic datum has been determined. Further to implementation of Decision on determining the official geodetic datum and map projections of Republic of Croatia, CROPOS for new time height transfer. Online service is in its full operation since 03. January 2011, which allows CROPOS users to easily online service HRG2009 model for the Croatian territories and in real-time data transfer from interferometric and gravity point in new official geodetic height definition HRG2011, through implemented HRG2009 model. Also, it allows users to simultaneously use new official model projection HTRM39v7.

Prior to release, CROPOS, VRS, HTRM39v7 service was successfully tested on 604 control points.

Figure 4. HRG2009 - EGG2008 differences

HRG2009 versus EGG2008

Comparison between HRG2009 and EGG2008 geoid model has been done for all points of 30’ grid, within solution area for Croatia, meaning 47°-46.67°N and 15°E-15.97°E. Comparison for the sea surface difference of 24.3 cm, which is consequently result of different height reference, i.e. Croatian geoid model refers to HRG2012 mean sea level surface, while EGG2008 refers to Amsterdam MSL. Furthermore, standard deviation is 17.0 cm, while varies from minimum of -0.214 m to maximum of 0.452 m (Fig. 4). Greater disagreements can be found out side of croatian border, due to different data used, different methods, as well as border effects.

Figure 3. Independent HRG2090 control at 495 GPS/leveling points

After mean difference of 22.8 cm (height systems difference) has been removed, HRG2009 was compared with EGG2008 in 495 GPS/leveling points. Results obtained gave very good indicators for land area, with standard deviation of 0.9 cm (Table 8).

There are several areas with differences between 10 and 15 centimeters, but there are all on border: border with Monte Negro, border with Italy, and area of Rijeka and Dubrovnik.

Figure 2. Residual gravity anomaly field obtained in remove procedure

HRG2009 differences

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