Investigation of the use of deflections of vertical measured by DIADEM camera in the GSVS11 Survey

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Outline

• Goal: to compute a geoid profile of 325 km long to the sub-cm differential accuracy using GSVS11 data (GPS, Leveling, DoV, gravity, DEM data)

• Data accuracy of GSVS11

• Geoid computation using DoV data, and the effect of the systematic bias on the geoid along the line

• Geoid profile using spectral combination of GPSL and DoV

• Geoid models evaluation and differential accuracy estimation

• Conclusions and future work
Location of GSVS11

325 km
218 points
1.5 km spacing
Accuracy of gravimetric and geometric data of GSVS11

At each benchmark (~1 mile spacing along the line):
- Ellipsoidal height (24-48 hours GPS obs. time), OPUS project used for data processing ($\sigma = \pm 3-4$ mm)
- Leveled elevation of the 1st order class II specification ($\sigma = \pm 0.7\sqrt{d}$ mm, ~13 mm over 325 km)
- DoV observations by DIADEM camera ($\sigma = \pm 0.1^\prime$)
- Absolute and relative gravity ($\sigma < \pm 20$ microGal)
DoV geoid profile computation

Dynamic method (Hoffmann-Wellenhof and Moritz, 2006, chapter 8.13)

1. Correct the normal gravity curvature from the observed surface DoV

2. Compute the height anomaly using the corrected DoV, take into account the height changes of the topography (non-equipotential surface)

3. Convert the height anomaly into the geoid using the Bouguer anomaly
Geoid differences

![Graph showing geoid differences with various lines representing different models such as DoV-EGM08, DoV-GPSL, DoV-xUSGG11, and xUSGG11-GPSL. The x-axis represents distance from north to south in kilometers, and the y-axis represents centimeters.](image-url)
### Geoid differences (in mm)

<table>
<thead>
<tr>
<th></th>
<th>GPSL-DoV</th>
<th>USGG09-DoV</th>
<th>EGM08-DoV</th>
<th>xUSGG11-DoV</th>
<th>xUSGG11-GPSL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>-29.7</td>
<td>-30.2</td>
<td>-29.6</td>
<td>-34.5</td>
<td>-4.8</td>
</tr>
<tr>
<td><strong>STD</strong></td>
<td>25.4</td>
<td>33.0</td>
<td>32.6</td>
<td>29.6</td>
<td>9.5</td>
</tr>
<tr>
<td><strong>RMS</strong></td>
<td>39.1</td>
<td>45.0</td>
<td>44.1</td>
<td>45.5</td>
<td>10.7</td>
</tr>
<tr>
<td><strong>Min.</strong></td>
<td>-16.7</td>
<td>-77.0</td>
<td>-83.0</td>
<td>-88.0</td>
<td>-40.4</td>
</tr>
<tr>
<td><strong>Max.</strong></td>
<td>89.3</td>
<td>28.0</td>
<td>30.0</td>
<td>10.0</td>
<td>32.8</td>
</tr>
</tbody>
</table>
Contribution of “suspected” biases in DoV data to the geoid

Mean $x_1 = -0.075''$
Mean $\eta = 0.009''$
Power spectral density (PSD) of the residual geoids
Spectral combination (GPSL+DoV)

GPSL geoid is accurate at long wavelength, and DoV geoid is precise at short wavelength:

\[ N_{comb} = \sum_{i=0}^{N} w_i \phi_{GPSL}(f_i) + \sum_{i=0}^{N} (1 - w_i) \phi_{DoV}(f_i) \]

\[ w_i = \begin{cases} 
1 & i \leq n_0 \\
0 & i > n_0 
\end{cases} \]

where \( n_0 \) is the cut-off frequency. The value used in this study corresponds to the wavelength of 96km.
High frequency error removed from GPSL geoid profile
(geoid model – Comb.) along the line

- USGG09-Comb.
- xUS GG11-Comb.
- EGM08-Comb.

Centimeter

Distance (N to S, km)
# Geoid comparison (model – Comb.)

<table>
<thead>
<tr>
<th></th>
<th>GPSL (mm)</th>
<th>USGG09 (mm)</th>
<th>EGM08 (mm)</th>
<th>xUSGG11 (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>-0.0</td>
<td>-0.4</td>
<td>0.1</td>
<td>-0.5</td>
</tr>
<tr>
<td><strong>STD</strong></td>
<td>7.6</td>
<td>16.9</td>
<td>17.2</td>
<td>6.7</td>
</tr>
<tr>
<td><strong>RMS</strong></td>
<td>7.6</td>
<td>16.9</td>
<td>17.2</td>
<td>8.2</td>
</tr>
<tr>
<td><strong>Min.</strong></td>
<td>-22.2</td>
<td>-28.0</td>
<td>-29.1</td>
<td>-18.2</td>
</tr>
<tr>
<td><strong>Max.</strong></td>
<td>33.0</td>
<td>26.7</td>
<td>35.1</td>
<td>8.7</td>
</tr>
</tbody>
</table>
Estimation of differential accuracy of the combined geoid profile

\[ \sigma^2 (x_{USGG11} - comb) \]

\[ = \sigma^2 (x_{USGG11}) + \sigma^2 (comb) \]

\[ = 6.7^2 \text{ mm}^2 \]

\[ \rightarrow \sigma^2 (x_{USGG11}) \leq 6.7^2 \text{ mm}^2 \]

\[ \sigma^2 (comb) \leq 6.7^2 \text{ mm}^2 \]

• Thus, the differential accuracy of the combined geoid profile is probably better than 5mm.

• Then the differential accuracy of xUSGG11 is around 5mm, and can’t be worse than 6.7 mm.
Conclusions(1)

• STD values of differences of geoid models and DoV geoid are over 30mm; the GRAV-D airborne gravity data enhanced geoid agrees with GPSSL geoid in 9.5mm (STD value).

• The DoV geoid tilt could be attributed to biases of 0.072” (N-S) and 0.019”(E-W) in DoV data.

• The combined geoid (GPSSL+DoV) may be better than 5mm of differential accuracy, all high frequency errors in GPSSL geoid are removed.
Conclusions(2)

• There is a 0.04 ppm slope between xUSGG11 and GPSL geoid (which one is tilted?)

• GRAV-D airborne gravity data enhanced geoid model xUSGG11 is revealed a differential accuracy of better than 6mm.

• DIADEEM camera DoV data could be useful for long traverses if the systematic biases are carefully calibrated.
Future Work

• Investigate the terrain effect on the DoV data interpolation and possible system biases removal

• Combine satellite gravity models (long wavelength) with DoV data (short wavelength) in geoid profile computation