Processing large volume GPS data via Bernese V4.2 software

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International Technical Laser Workshop on SLR Tracking of GNSS Constellations

50 Years of Satellite Geodesy and Geodynamics

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Metsovon Conference Center
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National Technical University of Athens (NTUA)
Metsovon Interdisciplinary Research Center (MIRC) of the NTUA
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Introduction

- Deformation monitoring studies combine large amount of GNSS data and offer high quality products (coordinates/velocities).
- Data analysis is performed via software packages applying statistical models (Least Squares/Kalman filter etc).
- Users and software products have to address the growing demands for accuracy, high resolution, observation volume, reliability estimates.
Data analysis

• Higher Geodesy Laboratory and Dionysos Satellite Observatory of NTUA have participated in a European inter-disciplinary research programme by establishing and maintaining a network throughout Central Greece, to study the long term tectonic behaviour.

• Two GPS campaigns are analyzed and discussed:
  1. Epoch 1997.76 (11 days of observations - 150 network points)
  2. Epoch 2005.76 (10 days of observations - 71 network points)

• Both networks were tied to the ITRF2000 via 7 IGS stations

• The results of the 30 first order network common points are discussed here.
Figure 1

Epoch 1997.76 1st order network

Epoch 2005.76 1st order network
Figure 2  IGS stations used for referring to the ITRF 2000
• Data analyzed by BERNESE V4.2 GPS software
• Precise IGS orbits and corresponding pole
• IGS phase eccentricity file
• Baseline approach was used
• Ambiguities resolved using the Q.I.F (Quasi Ionosphere Free) method with rejection limit of 85%.
• Ionosphere model used for baselines longer than 400km
• Daily normal equations evaluated for the adjustment / estimation procedures.
Solution A: daily coordinate estimations as a non-weighted average using only sub-programme GPEST

Solution B: Combined adjustment of daily normal equations, using parameter elimination for troposphere parameters (via sub-programme ADDNEQ)

Parameter elimination is an algorithm to reduce the volume of parameters, while no a-priori information is lost. Troposphere parameters occupy the biggest part of NEQ files.

Solution C: Combined adjustment of daily coordinates using corresponding daily VarCovar matrices (via sub-programme COMPAR)

A-priori information are the results from sub-programme GPEST (Solution A)
Final estimates were calculated by **three different methods**: Solution A, Solution B and Solution C.

**Figure 3**
Comparison of the Solutions

Figure 4

- Coordinate discrepancies vary up to 6mm for the *horizontal* and up to 18mm for the *height components*
- Discrepancies are in most cases within observation noise
Figure 4 (cont.)

- Coordinate discrepancies vary up to 6mm for the horizontal and up to 20mm for the height components.
- Discrepancies are in most cases within observation noise.
• Solutions B and C provide practically identical results

![Figure 4 (cont.)](image)

<table>
<thead>
<tr>
<th>discrepancies between solutions</th>
<th>Epoch 1997.76</th>
<th>Epoch 2005.76</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>mean</td>
</tr>
<tr>
<td>ΔN (mm)</td>
<td>ΔE (mm)</td>
<td>ΔU (mm)</td>
</tr>
<tr>
<td>0.1</td>
<td>-0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>1.8</td>
<td>5.7</td>
<td>13.5</td>
</tr>
</tbody>
</table>

Table 1

• Coordinate discrepancies vary up to 6mm for the horizontal and up to 18mm for the height components

• Discrepancies are in most cases within observation noise
Error Analysis

• Each estimate is accompanied by an a posteriori standard error value for all solutions. Apart from solution A, quality estimates are unrealistic (large volume of data → excessive degrees of freedom).

• Despite the small discrepancies in coordinate estimates between the Solutions B and C the corresponding a posteriori standard error values are not the same.

RMS2 differences from solutions B and C

Figure 5
• After each day is processed two slightly different a posteriori standard error values (in our case < 0.8mm) may be computed:

→ One is computed from the sub-programme GPEST to be used by the sub-programme COMPAR (Solution C) \( \sigma_{0Gi} \).

→ The second one from the sub-programme ADDNEQ (Solution B) \( \sigma_{0Ai} \).

• Therefore the a priori variance of the combined solutions (B or C) may be calculated from:

\[
\sigma_{0c}^2 = \frac{\sum r_i \cdot \sigma_{0i}^2}{\sum r_i} \quad \text{(sum over all days)}
\]

where:

\( \sigma_{0c}^2 \) : the apriori variance of unit weight of the combined solution,

\( r_i \) : the degrees of freedom for day \( i \),

\( \sigma_{0i}^2 \) : the variance of unit weight computed from day \( i \)
**Table 2**  Apriori and a-posteriori standard errors of unit weight for the combined solution (B and C) and for both epochs of GPS observations

<table>
<thead>
<tr>
<th></th>
<th>Solution B</th>
<th>Solution C</th>
<th>Epoch</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a-priori (mm)</strong></td>
<td>( \sigma_{0Ai} )</td>
<td>1.2</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>1.4</td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td><strong>a-posteriori (mm)</strong></td>
<td>( \hat{\sigma}_0 )</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>( \hat{\sigma}_{OAC} )</td>
<td>20.1</td>
<td>13.1</td>
</tr>
<tr>
<td></td>
<td>( \hat{\sigma}_0 )</td>
<td>1.5</td>
<td>25.4</td>
</tr>
<tr>
<td></td>
<td>( \hat{\sigma}_{OCC} )</td>
<td></td>
<td>23.9</td>
</tr>
</tbody>
</table>

- \( \sigma_{0Ai} \): apriori standard error of unit weight computed from day \( i \) from the sub-programme ADDNEQ
- \( \sigma_{0Gi} \): apriori standard error of unit weight computed from day \( i \) from the sub-programme GPEST
- \( \hat{\sigma}_0 \): a-posteriori standard error of unit weight of the combined solution
- \( \hat{\sigma}_{OAC} \): a-posteriori standard error of unit weight of the coordinate group computed from ADDNEQ (Solution B)
- \( \hat{\sigma}_{OCC} \): a-posteriori standard error of unit weight for coordinate comparison computed from COMPAR (Solution C)
• A posteriori standard error values for solution C seem to be in close (linear) relation with standard errors from solution A

• A linear model was applied to the two epochs data sets. Residuals disperse significantly for standard error values > 20mm.

• Discarding such points and re-applying the linear model, resulted in almost identical parameters (for all components and both epochs).
Figure 6
Table 3 Parameters of the linear model for each coordinate component and both epochs

<table>
<thead>
<tr>
<th>Component</th>
<th>X</th>
<th></th>
<th>Y</th>
<th></th>
<th>Z</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
<td>a</td>
<td>b</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>Epoch 1997.76</td>
<td>0.36</td>
<td>0.7</td>
<td>0.39</td>
<td>0.2</td>
<td>0.37</td>
<td>0.7</td>
</tr>
<tr>
<td>Epoch 2005.76</td>
<td>0.42</td>
<td>-0.2</td>
<td>0.34</td>
<td>0.3</td>
<td>0.44</td>
<td>-0.3</td>
</tr>
</tbody>
</table>

- So far no reliable conclusions maybe reached.
## Conclusions

<table>
<thead>
<tr>
<th>Solution A provides realistic standard error values</th>
<th>It is rather time-consuming (not fully automated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- It is rather time-consuming (not fully automated)</td>
<td>- Can be heavily influenced by errors since it considers equally weighted estimates</td>
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<td></td>
</tr>
</tbody>
</table>

- **Solution B** provides reliable coordinate estimates
  - Offers a wide variety of options
  - Can process all kind of parameters

- **Solution C** offers reliable coordinate estimates
  - Easy to use
  - Standard error values seem to be in close relation with the values from Solution A
Thank you for your attention