Multi-constellation GNNS baseline solutions – a perspective from the user’s and developer’s point of view

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Outline:

• Introduction
• Post-Processing baselines SW evolution
• TBC v4.00 – New Generation of Static Baseline Processing
• CROPOS
• Baseline processing with GPS-only, GLONASS-only and combined GPS+GLONASS data using CROPOS
• Subnetwork baseline processing using Galileo data combination
• Conclusions
Introduction:

- The first GPS receiver was purchased in 1989
- Faculty of Geodesy introduced a satellite geodesy (GPS) in the curriculum since 1996
- Since the beginning, Trimble’s HW and SW solutions were used for static and kinematic (post-processing) applications
- SW: GPSurvey → Trimble Geomatics Office (TGO) → Trimble Business Center (TBC)
- PP SW evolution
- Example of Multi-constellation GNSS baseline solutions (GPS, GLONASS, Galileo)
Software Evolution in Trimble

- Long history in surveying software
- GPSurvey (TrimNet)
- TGO
- Terramodel
- VRSNet
- TBC
- Focus on the entire system solution
Post-Processing baselines SW evolution

- TBC v1.0 (2005): L1 Postprocessing Module
- TBC v1.11 (2007): Session editor, Time-based view, Internet download
- TBC v2.00 (2008): Optical (total station and level) data support
- TBC v2.11 (2009): .T02 format
- TBC v2.40 (2010): Multiple frequency (L1/L2/L5) baseline processing
- TBC v2.60 (2011): Multi-core CPUs by processing independent baselines
- TBC v2.80 (2012): Support for QZSS
Post-Processing baselines SW evolution

- TBC v3.00 (2013): 64-bit version, UAS support
- TBC v3.50 (2015): Support GNSS independent constellation processes (PP/PPK), including BeiDou only, GLONASS only, and BeiDou + GLONASS only
- TBC v4.00 (2017):
  - Automatic dynamic parameters Support for Differential Code Biases (DCB) for satellites via the Internet Downloads
  - Support for Earth Orientation/Rotation Parameter (EOP) models
CROatian Positioning System (CROPOS):

- 33 national GNSS stations + 18 GNSS stations from neighbouring networks
- ~70 km
- Estab. in 12/2008, ETRF2000 (R05), e=2008.83
- DPS, Highly Precise Positioning Service (HPPS); Geodetic Precise Positioning Service (GPPS)
- CROPOS is based on Trimble’s solutions: NetR5, Zephy Geodetic 2 wRadome, Trimble Pivot Web, VRS concept
- Currently CROPOS supports GPS and GLONASS observations
Baseline processing with GPS-only, GLONASS-only and combined GPS+GLONASS data using CROPOS GPPS:

- CORSes: ZABO, KARL, SISA, ZAGR
- 35 hours, 5 sec logging interval
- IGS Final Precise Ephemeris (GPS & GLONASS)
- IGS Final EOP
- ETRF 2000 (R05), e = 2008.83 → ITRF2014, e = 2017.33
- Two additional stations: GEOM (NetR9) & ZZZF (R10)
- TBC v4.00
- Baseline processing with 3 different data combinations: GPS-only, GLONASS-only, GPS+GLONASS
Baseline processing with GPS-only, GLONASS-only and combined GPS+GLONASS data using CROPOS GPPS:

- homogenous accuracy ($a = 8-9$ mm; $b = 6-7$ mm; $\sigma h = 27-30$ mm)
- CORS ZAGR coordinates comparison: ‘Measured-Reference’

<table>
<thead>
<tr>
<th>Combination</th>
<th>$\Delta E$ [m]</th>
<th>$\Delta N$ [m]</th>
<th>$\Delta h$ [m]</th>
<th>$\sigma E$ [m]</th>
<th>$\sigma N$ [m]</th>
<th>$\sigma h$ [m]</th>
<th>2D [m]</th>
<th>3D [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS only</td>
<td>-0.002</td>
<td>0.008</td>
<td>0.005</td>
<td>0.005</td>
<td>0.007</td>
<td>0.027</td>
<td>0.008</td>
<td>0.009</td>
</tr>
<tr>
<td>GLONASS only</td>
<td>0.001</td>
<td>0.008</td>
<td>0.001</td>
<td>0.006</td>
<td>0.006</td>
<td>0.032</td>
<td>0.008</td>
<td>0.008</td>
</tr>
<tr>
<td>GPS+GLONASS</td>
<td>-0.001</td>
<td>0.008</td>
<td>0.004</td>
<td>0.005</td>
<td>0.006</td>
<td>0.027</td>
<td>0.008</td>
<td>0.009</td>
</tr>
</tbody>
</table>

- all combinations have led to (2D) and (3D) spatial deviation < 1 cm
- GPS+GLONASS combination declared as the most reliable
- Coordinate precision of stations GEOM and ZZFP was assessed from the coordinate differences: GPS-GLONASS; GPS-(GPS & GLONASS); GLONASS – (GPS & GLONASS)
- GPS+GLONASS combination was pointed out as the most reliable
Subnetwork baseline processing using Galileo data combinations:

- GEOM (NetR9), ZZFP (R10), MRGJ (R10)

<table>
<thead>
<tr>
<th>Time window</th>
<th>PDOP range (min-max)</th>
<th>Number of SV</th>
<th>Duration (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01:26 – 03:45 UTC</td>
<td>2.98 – 582.64</td>
<td>4, 5, 6</td>
<td>140</td>
</tr>
<tr>
<td>11:41 – 14:25 UTC</td>
<td>7.37 – 828.78</td>
<td>4, 5</td>
<td>165</td>
</tr>
<tr>
<td>16:50 – 20:51 UTC</td>
<td>1.96 – 137.33</td>
<td>4, 5, 6</td>
<td>242</td>
</tr>
</tbody>
</table>
Subnetwork baseline processing using Galileo data combinations:

- 3 sessions, 7 different data combinations (GPS-only, GPS & GLO, GPS & GLO & GAL, GPS & GAL, GLO-only, GLO & GAL, GAL-only) → 21 project
- Minimally constrained adjustment with GEOM station being fixed
- All baselines were obtained with FIXED solution with one exception: GEOM → ZZFP (2nd session)
Subnetwork baseline processing using Galileo data combinations:

- Coordinates of the station ZZFP obtained with different data combinations were compared to the reference (GPS & GLONASS)
Subnetwork baseline processing using Galileo data combinations:

- Coordinates of the station ZZFP obtained with different data combinations were compared to the reference (GPS & GLONASS)

- Heights obtained from the combination (GPS+GLONASS+Galileo) have shown the smallest sum of departures from the reference value

- 3rd session being the longest in duration with better satellite visibility showed overall best results
CONCLUSION:

• Difference between reference coordinates of CORS ZAGR and those calculated in TBC v4.00 have shown to be at sub-cm level proving great potential

• Subnetwork featuring 3 stations were occupied by Galileo-enabled GNSS receivers leading to a 7-combination solutions

• Since Galileo constellation hasn’t been fully deployed, mission planning has shown to be an essential step in reaching a FIXED baseline solution

• By approaching the FOC, Galileo satellites are expected to provide an improvement in terms of availability, accuracy and reliability of coordinates determination
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