Enhancing the Swiss Permanent GPS Network for GNSS

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GLONASS data used for EUREF solutions

- swisstopo’s official contribution based on GLONASS data since GPS week 1400 (Nov. 2006)
- 4 stations equipped with combined GNSS receivers in swisstopo’s subnetwork
- Orbit information used from CODE (instead of IGS)
- Ambiguities not fixed
Enhancing the Swiss Permanent GPS Network (AGNES) for GLONASS

- Increasing number of operational GLONASS satellites
- Leica and Trimble with new GNSS receivers on the market
- Galileo: operational status delayed
- Decision swisstopo: Enhancement of AGNES for GLONASS (mainly due to RTK applications)
- Trimble NetR5 receivers and Zephyr GNSS antennas
Double station concept

“Double station“:
New antenna mount for GNSS antenna
New and old equipment run simultaneously

“Normal station“:
Antenna and receiver replacement
Double stations: Reference frame stability

Station Schaffhausen (SCHA)

→ Double stations help to maintain the consistency of the national reference frame
Double stations: Velocity estimation

- GLONASS
- GALILEO

Formal error [mm/year]

- Antenna change + jump
- No antenna change

3 more years without changes
= 10 years with 2 changes

\[ \sqrt{n^3} \]
Individual calibration of the antennas

• Estimation of absolute antenna calibration models by means of calibration robots (Geo++)
• Elevation and azimuth-dependent calibration values
• Currently, only determination of type values for GLONASS
• Individual calibration values for post-processing applications, not for RTK positioning service
Individual antenna calibration values ↔ antenna type calibration (EUREF solution)

4 of 30 stations with individual calibration values in swisstopo’s subnetwork
Post-processing long baselines: Influence on the repeatability (EUREF solution)

GPS solution: Station WTZR, 7 weeks
Post-processing long baselines: Influence on the repeatability (EUREF solution)

GPS/GLONASS solution: Station WTZR, 7 weeks
Post-processing long baselines:
Influence on the coordinates (EUREF solution)

Difference between GPS solution and GPS/GLONASS solution:

<table>
<thead>
<tr>
<th>Location</th>
<th>North [mm]</th>
<th>East [mm]</th>
<th>Up [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BORJ (Borkum, Ge)</td>
<td>- 0.3</td>
<td>0.1</td>
<td>- 0.7</td>
</tr>
<tr>
<td>HELG (Helgoland, Ge)</td>
<td>0.1</td>
<td>- 0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>WTZR (Wettzell, Ge)</td>
<td>0.1</td>
<td>0.0</td>
<td>0.3</td>
</tr>
<tr>
<td>HOE2 (Hoernum, Ge)</td>
<td>0.0</td>
<td>0.1</td>
<td>- 0.1</td>
</tr>
</tbody>
</table>
GNSS tests Zimmerwald: Short baselines

ZIMM Trimble NetRS (GPS)

ZIMT Trimble NetR5 (GNSS)

ZIMJ Javad (GNSS)

ZIML Leica 1230 (GNSS)
Short baselines: Repeatability BSW5.0+; 7 days

L1 solution

- ZIMT GPS
- ZIMT GNSS
- ZIML GPS
- ZIML GNSS
- ZIMM GPS
- ZIMM "GNSS"

[Graph showing data for each baseline with error bars indicating repeatability.]
Short baselines: Repeatability BSW5.0+; 7 days

L3 solution

→ Further tests by CODE (inter-system phase biases, initialisation for ambiguity fixing, ...)

EUREF Symposium 2007, London
Swiss Federal Office of Topography swisstopo
June 6 to 9, 2007
Real-Time Kinematic (RTK) tests using GNSS data

- 5 km baseline (Zimmerwald to swisstopo building)
- Base station: Trimble NetR5 receiver
- Rover: Leica 1230GG receiver
- Initializations every 30 minutes during 3 days (VRS monitor box)
- Elevation cut-off: 10° and 30°
RTK tests: 10 degree cut-off angle

<table>
<thead>
<tr>
<th>Elevation cut-off</th>
<th>Satellite system</th>
<th>Initialisation time [s]</th>
<th>Availability [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>10°</td>
<td>GPS</td>
<td>3 s</td>
<td>100 %</td>
</tr>
<tr>
<td></td>
<td>GPS+GLONASS</td>
<td>3 s</td>
<td>98 %</td>
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</tbody>
</table>
RTK tests: 30 degree cut-off angle

<table>
<thead>
<tr>
<th>Elevation cut-off</th>
<th>Satellite system</th>
<th>Initialisation time [s]</th>
<th>Availability [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>30°</td>
<td>GPS</td>
<td>67 s</td>
<td>62 %</td>
</tr>
<tr>
<td></td>
<td>GPS+GLONASS</td>
<td>46 s</td>
<td>79 %</td>
</tr>
</tbody>
</table>
Conclusions

- GLONASS integration: First step towards GALILEO
- Learning process (post-processing). Further improvements possible by more satellites, more stations, and software enhancements
- We expect benefits mainly for real-time applications in
  - increased availability under difficult conditions
  - reduced initialisation times
  whereas accuracy does not (yet) improve
- The first equipment replacements will be done next week!
## RTK tests: Availability, time for initialisation

<table>
<thead>
<tr>
<th>elevation cut-off</th>
<th>satellite system</th>
<th>init [s]</th>
<th>east [mm]</th>
<th>north [mm]</th>
<th>horizontal [mm]</th>
<th>height [mm]</th>
<th>availability [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>10°</td>
<td>GPS</td>
<td>bias</td>
<td>3.0</td>
<td>-8.7</td>
<td>1.8</td>
<td>11.1</td>
<td>15.0</td>
</tr>
<tr>
<td></td>
<td>std</td>
<td>1.6</td>
<td>4.2</td>
<td>5.9</td>
<td>7.2</td>
<td>11.3</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>GPS+GLONASS</td>
<td>bias</td>
<td>2.8</td>
<td>-9.6</td>
<td>1.8</td>
<td>9.8</td>
<td>16.3</td>
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<td>std</td>
<td>0.4</td>
<td>4.9</td>
<td>10.4</td>
<td>11.5</td>
<td>10.3</td>
<td>-</td>
</tr>
<tr>
<td>30°</td>
<td>GPS</td>
<td>bias</td>
<td>67.5</td>
<td>-9.2</td>
<td>1.1</td>
<td>11.7</td>
<td>17.7</td>
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<tr>
<td></td>
<td>std</td>
<td>117.3</td>
<td>3.4</td>
<td>7.1</td>
<td>7.9</td>
<td>12.0</td>
<td>-</td>
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<tr>
<td></td>
<td>GPS+GLONASS</td>
<td>bias</td>
<td>46.3</td>
<td>-9.0</td>
<td>-0.3</td>
<td>11.7</td>
<td>15.5</td>
</tr>
<tr>
<td></td>
<td>std</td>
<td>103.9</td>
<td>3.7</td>
<td>7.7</td>
<td>8.5</td>
<td>14.2</td>
<td>-</td>
</tr>
</tbody>
</table>

std: standard deviation
Absolute antenna models: IGS

Vergleich von 132 IGS-Stationen:
Absolute und relative Antennenmodelle:
Erheblicher Einfluss (hauptsächlich Höhe)!
Influence des modèles d’antennes absolus: Groupes d’antennes (solution AGNES)

Differenz: Relativ zu absolut: Différence: relatif à absolu:

<table>
<thead>
<tr>
<th>GPS-Woche 1369</th>
<th># Antennen</th>
<th>Differenz [mm]</th>
<th>Standardabweichung [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Nord</td>
<td>Ost</td>
</tr>
<tr>
<td>Trimble Chokering</td>
<td>14</td>
<td>0.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Trimble Microcentered</td>
<td>21</td>
<td>1.9</td>
<td>0.4</td>
</tr>
<tr>
<td>LEIAT504 LEIS</td>
<td>5</td>
<td>-1.2</td>
<td>-0.7</td>
</tr>
<tr>
<td>ASHTECH (Divers)</td>
<td>16</td>
<td>-0.5</td>
<td>-1.1</td>
</tr>
</tbody>
</table>

- Differenz = f (Antennentyp)
- Extremwerte Nord/Ost für einzelne Antennen bis 6 mm
- Différence = f (type d’antenne)
- Valeurs extrêmes nord/est pour certaines antennes jusqu’à 6 mm
Change of the reference frame
ITRF2000 → ITRF2005

AGNES network:
- North: -12 mm
- East: 1 mm
- Height: -19 mm

Change GPS week 1400, November 2006