Inconsistency between Maps and Satellite Positioning Results caused by Crustal Movements

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1.1. Background

In recent years, smartphones and car navigation systems have been widely used. On the other hand, the position gap between the satellite positioning result and the map has surfaced.

Factors of the position gap:

1. Due to the precision of satellite positioning and the quality of the map.
2. Due to the difference of the geodetic datum.
3. Due to crustal movements.
1.2. Objective

1. To provide a solution for inconsistency of map and satellite positioning results.
   - Semi-Dynamic Reduction (SDR)

2. To verify how far the map and result of PPP-RTK (CLAS) deviate.

3. Verification about SDR

   CLAS (Centimeter Level Augmentation Service)
   - One of augmentation data sent from QZSS
   - Created from observation data of some control points (CORS) around the user

Figure 1: crustal movements (2011-2016)
Source: GSI
2.1. Semi-dynamic correction

• In Japan
  ➢ Geodetic datum: Semi-dynamic
  ➢ Crustal movement correction: Semi-dynamic correction

• But...
  ➢ Can’t correct the deformation up to maximum 15 months.

Figure 2: Semi-dynamic correction and SDR
2.2. Semi-dynamic reduction

• Specific conditions
  ➢ CORS : GEONET (about 1300 stations)
  ➢ Grid : about 5km × 5km
3. Condition of observation

- Area: Tohoku region
- Points: Rifu, Kesennuma, Murayama, Watari, Fukushima
- Time: 1 [h]
- Out cycle: 1[Hz]
- Satellite systems: GPS/QZSS
- Positioning method: PPP-RTK

Figure 4: control points (CORS)
Source of map: GSI
4.1. Result of CLAS

- DRMS is within 1.5 cm at almost points.
- Fukushima’s value is slightly scattered.

<table>
<thead>
<tr>
<th>Location</th>
<th>Std. N-S[m]</th>
<th>Std. E-W[m]</th>
<th>DRMS[m]</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rifu</td>
<td>0.006</td>
<td>0.005</td>
<td>0.008</td>
<td>3601</td>
</tr>
<tr>
<td>Kesennuma</td>
<td>0.005</td>
<td>0.004</td>
<td>0.007</td>
<td>3601</td>
</tr>
<tr>
<td>Murayama</td>
<td>0.004</td>
<td>0.004</td>
<td>0.006</td>
<td>3601</td>
</tr>
<tr>
<td>Watari</td>
<td>0.012</td>
<td>0.007</td>
<td>0.014</td>
<td>3601</td>
</tr>
<tr>
<td>Fukushima</td>
<td>0.041</td>
<td>0.067</td>
<td>0.078</td>
<td>3601</td>
</tr>
</tbody>
</table>

Table 1: statistics of CLAS’s result

Figure 5: scatterplot
4.2. Position gap

<table>
<thead>
<tr>
<th></th>
<th>N-S[m]</th>
<th>E-W[m]</th>
<th>Horizontal Distance[m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rifu</td>
<td>-0.325</td>
<td>0.876</td>
<td>0.934</td>
</tr>
<tr>
<td>Kesennuma</td>
<td>-0.338</td>
<td>0.993</td>
<td>1.049</td>
</tr>
<tr>
<td>Murayama</td>
<td>-0.268</td>
<td>0.872</td>
<td>0.912</td>
</tr>
<tr>
<td>Watari</td>
<td>-0.278</td>
<td>0.808</td>
<td>0.854</td>
</tr>
<tr>
<td>Fukushima</td>
<td>-0.121</td>
<td>0.701</td>
<td>0.711</td>
</tr>
</tbody>
</table>

*The map is created based on the control point.

- Position gaps of horizontal direction are about 0.7 m to 1 m.
- The cause of large movements is post-seismic crustal movements.

Figure 6: position gap  
Source of map: GSI
4.3. Result corrected by SDR

Table 3: position gap (corrected by SDR)

<table>
<thead>
<tr>
<th>Location</th>
<th>N-S [m]</th>
<th>E-W [m]</th>
<th>Horizontal Distance [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rifu</td>
<td>0.006</td>
<td>-0.022</td>
<td>0.023</td>
</tr>
<tr>
<td>Kesennuma</td>
<td>0.005</td>
<td>-0.023</td>
<td>0.024</td>
</tr>
<tr>
<td>Murayama</td>
<td>0.015</td>
<td>-0.028</td>
<td>0.032</td>
</tr>
<tr>
<td>Watari</td>
<td>0.003</td>
<td>-0.027</td>
<td>0.027</td>
</tr>
<tr>
<td>Fukushima</td>
<td>0.018</td>
<td>-0.035</td>
<td>0.039</td>
</tr>
</tbody>
</table>

- Position gaps of horizontal distance are less than 4 cm at all observed points.

Figure 7: comparison of position gap
5. Conclusion

• Position gap
  ➢ About 0.7 m to 1 m in Tohoku area.

• The effect of SDR
  ➢ The horizontal difference is less than 4 cm at all points.

  By using SDR, it's enable to use the map with higher accuracy.

• Future Investigation
  ➢ Influence on grid pitch change.
  ➢ Study of correction in height direction.