Experimental Assessment of Achievable Accuracy of GNSS-Derived Heights from Carrier Phasc-Based Positioning Techniques for Ellipsodially Referenced Hydrographic Surveys

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Introduction

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Hydrographic survey has traditionally been performed for establishing nautical charts for safety of navigation, but has now a vital role in coastal zone management.

Costal zone encompasses a wide belt along the shoreline including the land and sea.

Integration of hydrographic and topographic data is essential for the analysis of coastal processes and management decision.

GNSS derived-heights on land and seas can be readily related to one another by GEOID, HYDRODYNAMIC & TTS MODELS.

The ellipsoid is convenient surface for field surveying, but it has only geometrical meaning.

The ellipsoidally referenced spatial information should be transformed to geodetic or chart datum.

SOME TECHNICAL ISSUES IN ERS

I. Data acquisition of high accuracy of GNNS

II. GNSS data processing scheme and its accuracy (uncertainty)

III. Vertical separation model (SEP) development and application

IV. Quality control of vertical offset, GNSS, motion, SEP.

V. Uncertainty associated with offset, GNSS, motion and SEP

VI. Data archive reference

KHOA is currently preparing to introduce the ERS concept to its bathymetric surveys.

Development of a best practice for the GNSS vertical positioning is a prerequisite.

Field trials were performed to collect satellite observables in static and kinematic modes.

The measurements were processed in medium-range PPK and PPP modes by two commonly used software (i.e., GrafNav & RTKlib).

To gain some experience and understanding of CPH-based techniques.

To access potential accuracy of the geometric height derived by the techniques.
GNSS Measurement & Methodology

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**GNSS Positioning Techniques for Hydrography**

1. **Pseudo-Range (PR)**

   \[ R_i^s = \rho_i^s + dp_i^s + c(dt_i^s - dT_i) + di_i^s + dr_i^s + dm_{i,R} + \varepsilon_{i,R}^s \]

2. **Carrier-Phase (CPH)**

   \[ \lambda_G \cdot \phi_i^s = \rho_i^s + dp_i^s + c(dt_i^s - dT_i) + \lambda_G \cdot N_i - di_i^s + dr_i^s + dm_{i,\phi} + \varepsilon_{i,\phi}^s \]

**GNSS Techniques depend upon**

- **Type of measurements used for estimation of coordinates** (PR Vs. CPH);
- **Method how errors boxed in the equations are corrected** (Point Vs. Relative).

To maximize positioning accuracy, CPH should be used for estimation process.
**GNSS MEASUREMENTS**

**Static Case**
- Five CORS stations in Korea
- 24 hours GPS data
- Over 250km of baseline length

**Kinematic Cases**

- **Turn-table Test**
  - Sokkia GRS2600 (dual-frequency)
  - 1Hz sampling rate
  - 70 min. including 10 min. static session

- **Survey Vessel Test**
  - Three of Sokkia GRX1
  - 1Hz sampling rate for 2 hours
  - Two hours kinematic session

Precise satellite orbit and clock were used for the data analysis.
SOFTWARE AND METHODOLOGY OF ACCURACY EVALUATION

Software#1 (SW-1)
- An open source program for GNSS positioning
- Standard and precise positioning algorithms with GPS, GLONASS, SBAS, QZSS
- Positioning mode for real-time and post-processing: Single, SBAS, DGPS, RTK, PPP

Software#2 (SW-2)
- Commercial post-processing software by Novatel
- Highly configurable processing engine that allows for the best possible static or kinematic accuracy.
- Differential and PPP processing
- Support for GPS L1/L2/L2C, GLONASS, BeiDou

Evaluation of achievable accuracy of ellipsoidal height estimated by medium-range PPK and PPP

Medium-Range Baseline PPK
- CODE precise satellite orbit
- Estimation of Iono. & trop.
- Ambiguity float solutions
- Combination of forward & backward processing

Short Baseline PPK
- Generation of reference for accuracy evaluation
- Ambiguity fixed solutions
- Usage of the nearest base station (e.g., shorter than 3km)

PPP - Kinematic
- CODE precise satellite orbit
- CODE 5 sec. satellite clock
- Ambiguity float solutions
- Combination of forward & backward processing

Comparison!

Comparison!
Test Results & Discussion

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STATIC TESTS: MEDIUM-RANGE PPK

- CHJU & PUSN (302km) -
  ![Graph 1](chart1.png)

- KANR & PUSN (280km) -
  ![Graph 2](chart2.png)

- SEOS & PUSN (288km) -
  ![Graph 3](chart3.png)

- CHJU & PUSN (302km) -
  ![Graph 4](chart4.png)

- KANR & PUSN (280km) -
  ![Graph 5](chart5.png)

- SEOS & PUSN (288km) -
  ![Graph 6](chart6.png)

- SW-1 -
  ![Graph 7](chart7.png)

- SW-2 -
  ![Graph 8](chart8.png)

✓ Three baseline solutions were generated by each software.
✓ Time-series of coordinate differences between PPK-derived and published height.
STATIC TESTS: PPP-KINEMATIC

- CHJU

- KANR

- SEOS

- PUSH

- SW-1

- SW-2
Accuracy of PPK and PPP is almost equivalent (PPK: ±5 – ±7cm, PPP: ±4 – 7cm except for PPP at PUSN).

Solutions from SW-2 are slightly more accurate than those of SW-1.
PPK results was derived with respect to SEOS station: baseline length was about 260Km.

Bias is observed in PPP solution; it seems to be caused by reference epoch difference between IGS08 and KGD 2002.
PPK solutions are slightly more accurate than that of PPP.

Accuracy of PPP is around ±10 cm; that of PPK is better than ±10 cm.

Accuracy of PPK-KANR from SW-2 is superior to that of SW-1, but in other two cases SW-1 is a little bit better.
The experiment was conducted around West Nakdong River in Busan, Korea.

GPS observation was made for approximate 2 hours by 3 rover receivers.
Bias is clearly seen in these results, except for PPK-SEOS. Considering characteristics of errors in measurement models, it seems to be induced by residual troposphere.
S/W does not much impact into accuracy, but SW-2 provides more stable solutions.

GNSS-derived height accuracy by PPP ranges from about $\pm 10$ cm to 15 cm.
SURVEY VESSEL TEST: RMSE OF MEDIUM-RANGE PPK

- Accuracy highly depends on selection of reference.
- PPK is less stable than PPP.
- Baseline distance is not coupled with accuracy.
- This might be residual relative troposphere caused by meteorological condition.

Some meteorological parameters during the test:

<table>
<thead>
<tr>
<th>Site</th>
<th>Temp. (°C)</th>
<th>Humid. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KANR</td>
<td>25 - 26</td>
<td>68 – 75</td>
</tr>
<tr>
<td>SEOS</td>
<td>28 - 29</td>
<td>84 – 90</td>
</tr>
<tr>
<td>SNJU</td>
<td>31 - 32</td>
<td>59 – 61</td>
</tr>
<tr>
<td>Testing Area</td>
<td>27 - 30</td>
<td>79 - 86</td>
</tr>
</tbody>
</table>
Concluding Remarks

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For future adaptation the ERS concept in Korean hydrographic society, the CPH-based GNSS positioning techniques have been tested in terms of accuracy on static and kinematic mode by using the two software packages.

Performance of the two software packages is comparable in both the CPH-based techniques as the accuracy differs only few centimetres level.

Although results of the static test is more accurate than those of the kinematic, it is somewhat overestimated because temporal residual tropospheric delay for 24 hours evened out in the RMSE computation.

Comparing the medium-range PPK to the PPP, the latter’s accuracy is more consistent, and that of the former varies against selection of the reference station.

As a consequence of the tests, achievable accuracy of the PPP with 1-σ confidence level is better than ± 16.1 cm, whereas that of the medium-range PPK is around ± 22.0 cm.

Because the experiments performed in this study are limited to the number and the size of testing samples, more intensive analysis under various survey conditions are highly recommenced in future for more reliable accuracy assessment.
Thank you for your attention ......