P3: 010

Enhancing Multi-GNSS Single Point Positioning with IGS RTS Corrections

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1. Motivation

The free services of the Global Navigation Satellite Systems (GNSS) can provide positioning, navigation, and timing (PNT) in Single Point Positioning (SPP) mode. Therefore, this mode is widely used in aerial, marine, and land navigation, as well as in various geophysical applications. However, the accuracy of the single-frequency SPP mode is limited by the quality of broadcast satellite orbit and clock corrections and ionospheric correction algorithms (ICAs). In recent years, the International GNSS Service (IGS) has started to provide access to precise products in real-time through the Real-Time Service (RTS). The RTS products consist of orbit and clock corrections, code biases, as well as experimental ionospheric delays. These products are streamed over the Internet in the IGS state space representation (SSR) format. Although the RTS products are designed primarily to support real-time Precise Point Positioning (PPP) mode, in this study, we investigate their applicability to improve the current performance of single-frequency SPP-based navigation.

2. Data sets and methodology

- Test period: 10-16 March 2024 (DOY 70-76)
- Data type: RINEX v3 observation files from 30 IGS stations
- Pseudorange observations: GPS [C1C], GLONASS [C1P], Galileo [C1C/X], BDS-3 [C2I]
- Products: broadcast, RTS, and final corrections (see Sec. 3)
- Positioning model: Single Point Positioning (single-frequency, single epoch)
- Interval: 180 s
- Elevation cut-off: 15°
- Statistics: 95th percentiles of horizontal and vertical positioning errors (HPE95% and VPE95%, respectively)

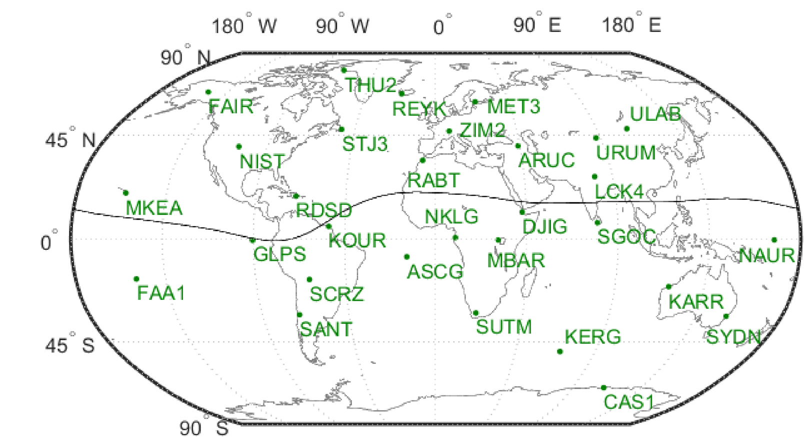

Fig. 1 GNSS-tracking stations used for evaluation

3. Results – example for mid-latitude (ZIM2) and low-latitude (GLPS) stations

The single-frequency SPP results were calculated using different multi-GNSS products:

1. Broadcast navigation data (**BRDC**) presenting the current performance of single-frequency code-based navigation. Orbit, clock, and group delay data were derived from the daily, merged broadcast ephemeris files provided by IGS. The NTCM G model based on Galileo Az parameters was applied to derive ionospheric delay corrections.
2. The combined IGS RTS orbit, clock, bias, and ionospheric corrections (**IGS RTS**) were used to support the standard SPP mode and, consequently, to investigate the IGS RTS applicability to improve the standard SPP solution.
3. The final orbit, clock, and bias products provided by the Wuhan University IGS analysis center (**WUM FIN**) with global ionosphere maps provided by the CODE Ionosphere Associate Analysis Center were used to obtain a reference (most accurate) solution.

Note that the availability of satellite corrections varies depending on the product used. However, a multi-GNSS solution usually allows the use of more than 20 satellites (Fig. 2).

Example positioning results for a mid-latitude European station (ZIM2) and an equatorial station (GLPS) are presented in Fig. 3. Such station selection aims to present the still unmitigated influence of the ionosphere on the results.

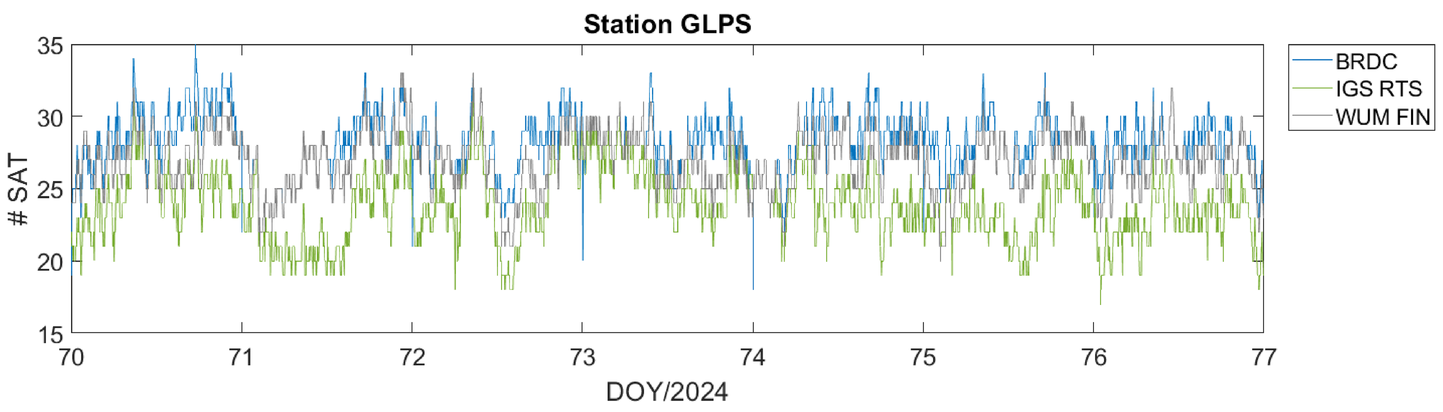

Fig. 2 Number of available GNSS satellites with corrections/products for GLPS station

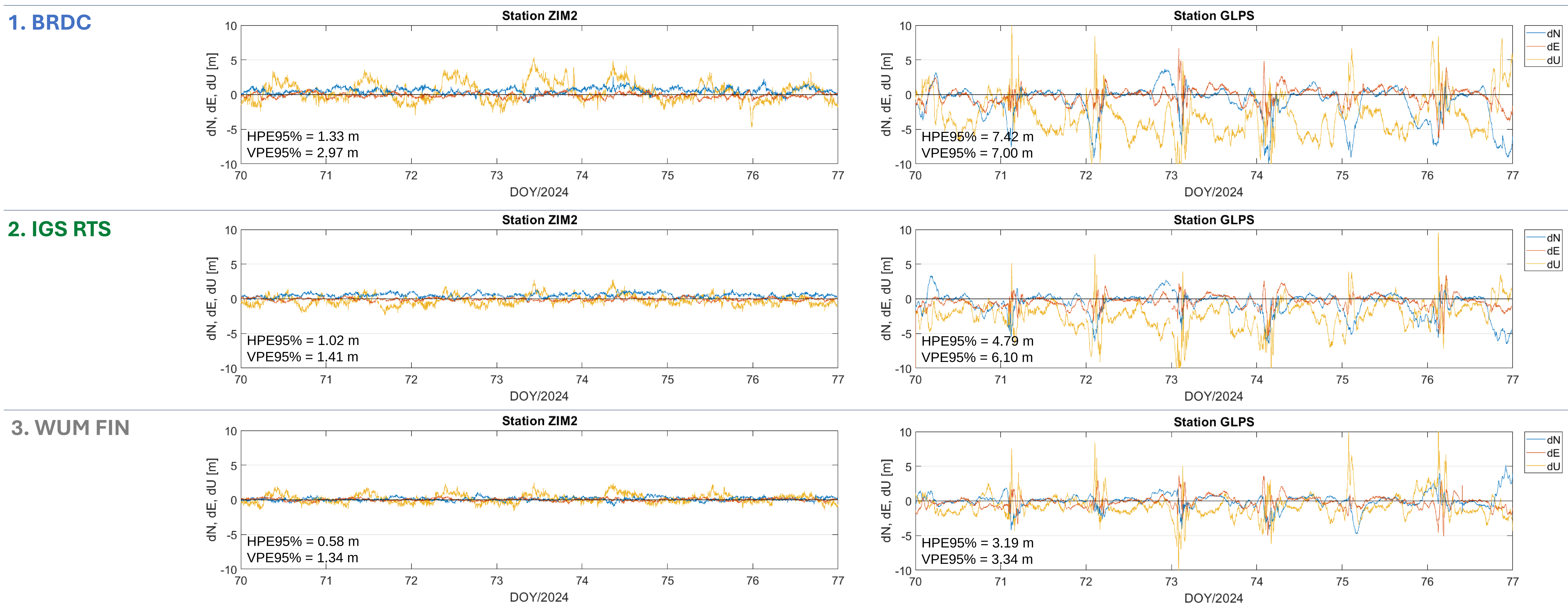

Fig. 3 Positioning results for ZIM2 (left) and GLPS (right) stations obtained with BRDC (top), IGS RTS (middle), and WUM FIN (bottom) products

4. Results – overall

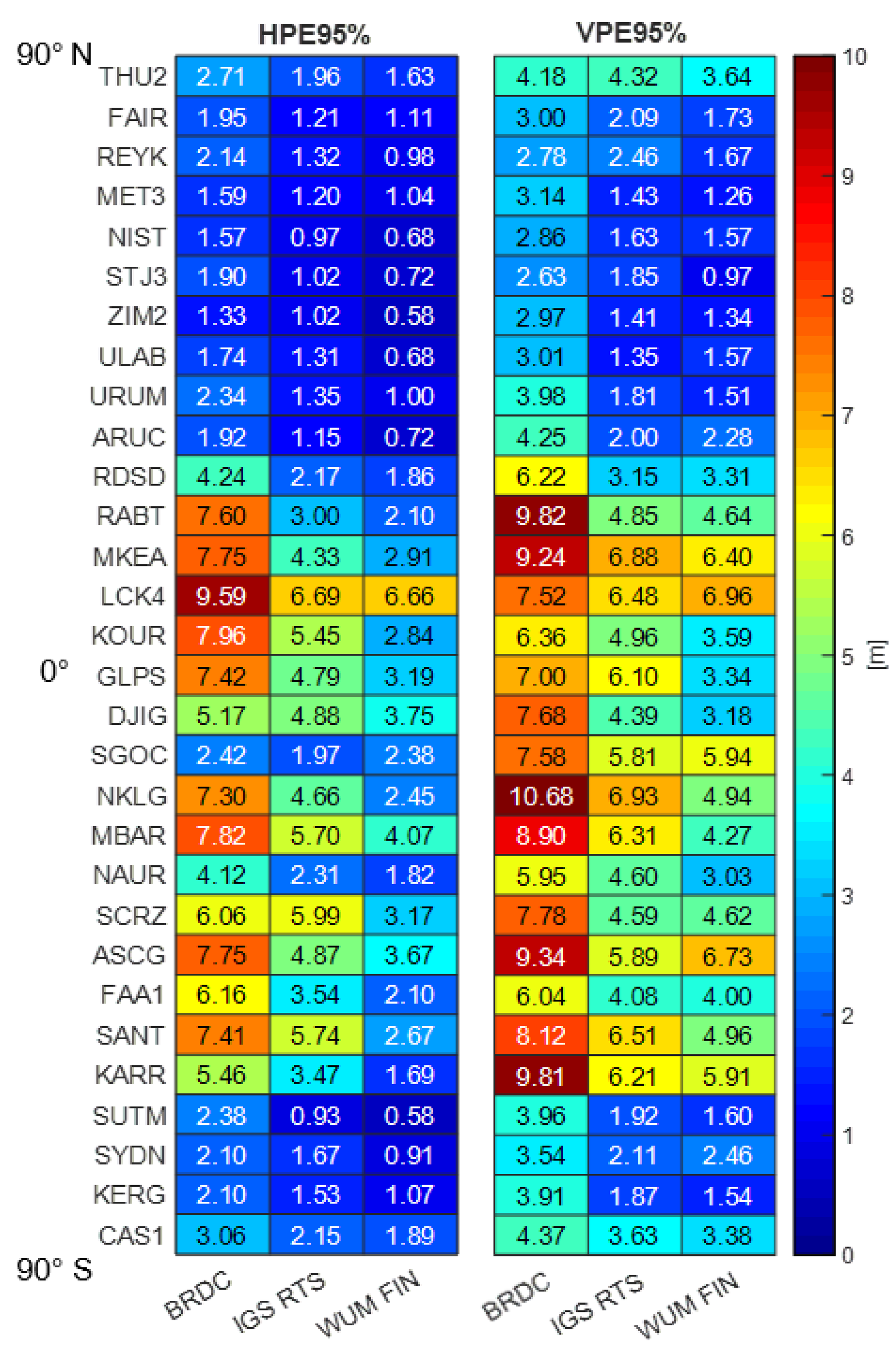

Fig. 4 HPE95% (left) and VPE95% (right) of each analyzed station for the three analyzed products. Stations sorted by geomagnetic latitude

One can observe that the positioning accuracy depends on the station's latitude. The obtained results are strongly correlated with one of the main sources of errors in positioning – the ionosphere. Regardless of the evaluated method used (BRDC, IGS RTS, or WUM FIN products), the low-latitude region is characterized by the lowest positioning accuracy. The application of IGS RTS corrections outperforms the standard SPP solution with one exception for THU2 station. This northern station is the only one that obtained worse vertical component accuracy with IGS RTS corrections than with BRDC data.

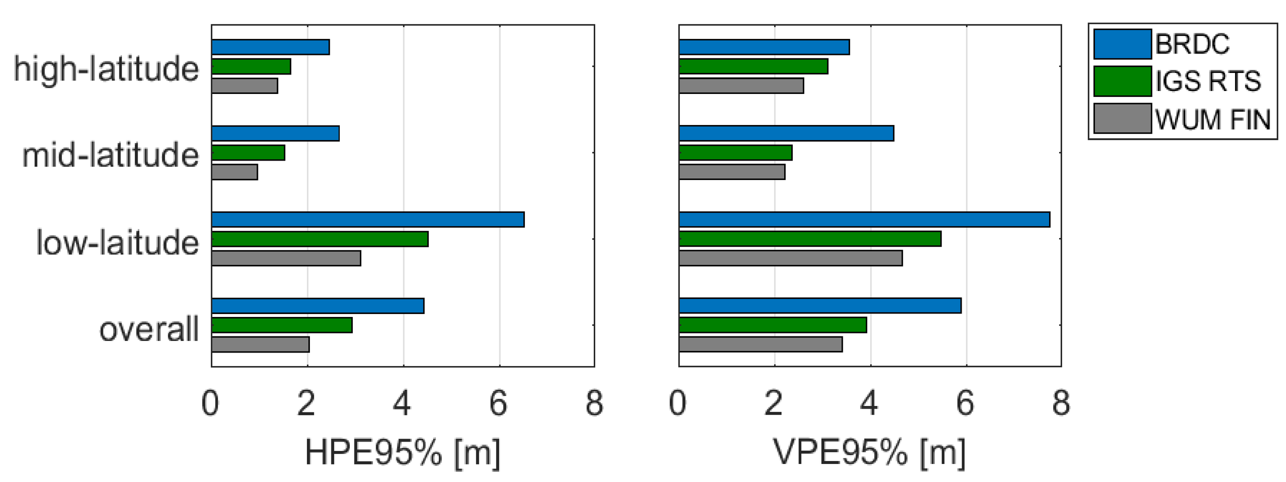

Fig. 5 Average HPE95% and VPE95% wrt geomagnetic latitudinal regions and for the overall data set

Table 1 Accuracy improvement of the IGS RTS solution in relation to BRDC

	Accuracy improvement	
	HPE95% [%]	VPE95% [%]
high-latitude	33	13
mid-latitude	42	47
low-latitude	31	29
overall	33	33

- High-latitude region: from 60° to 90° in both hemispheres.
- Mid-latitude region: from 30° to 60° in both hemispheres.
- Low-latitude region: from 30° S to 30° N.

5. Conclusions

The performance of the standard single-frequency SPP mode, based on broadcast navigation data, can be improved through the application of the IGS RTS products. Global average HPE95% and VPE95% values with the use of IGS RTS corrections amount to 2.95 m and 3.92 m, respectively. In comparison to broadcast data (4.43 m and 5.89 m for HPE95% and VPE95%, respectively), the IGS RTS corrections improve the accuracy of the positioning results by 33% horizontally and vertically over a one-week test period in 2024. This period is associated with increasing solar activity, and therefore, a greater impact of ionospheric delay on positioning results is visible. This is clearly evident when considering the results obtained with respect to the geomagnetic latitudinal regions. As expected, the positioning in the low-latitude region, strongly affected by the ionosphere, achieves the lowest accuracy. In turn, the mid-latitude region is characterized by the highest positioning accuracy, as well as the highest accuracy improvement when applying the IGS RTS corrections (42% and 47% for HPE95% and VPE95%, respectively). This is primarily because the mid-latitude region is covered by a dense network of GNSS stations used for ionosphere modeling. Moreover, the ionosphere is the most stable in this region.

Obviously, the best positioning results are obtained with the final products (WUM FIN). However, the application of IGS RTS corrections allows similar positioning accuracy to be achieved, especially in the mid-latitude region. The improvement in the real-time modeling of ionospheric delay is still a challenging and very important task that may further increase the positioning accuracy of code-based navigation, particularly in low-latitude region.