GFZ
Helmholtz Centre
POTSDAM

HELMHOLTZ CENTRE POTSDAM
GFZ GERMAN RESEARCH CENTRE
FOR GEOSCIENCES

Generating UPD for IGS combined products for ambiguity-fixing of real-time precise point positioning

Xingxing Li, Maorong Ge, Soeren Klose, Thomas Nischan, Jens Wickert
Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences
Telegrafenberg, 14473 Potsdam, Germany (maor@gfz-potsdam.de)

Introduction

The successful Real-Time Pilot Project is heading towards an official real-time Precise Point Positioning (PPP) service now. As is well known, integer ambiguity resolution of real-time PPP can significantly shorten the convergence time and improve the position accuracy as well. Therefore, ambiguity-fixing capability should be essential for the official service. We present here an approach for estimating the Uncalibrated Phase Delays (UPD) for PPP ambiguity-fixing using IGS combined real-time products.

UPD for IGS combined products

A number of studies are undertaken since years to overcome the UPD problem to recover the integer feature of the undifferenced ambiguities. Most of them are handling the UPDs in the clock estimation. Thus, the resulted UPDs are not always suitable for the IGS combined products due to possible inconsistency in models and algorithms.

In this contribution, we developed a new processing strategy to generate UPDs for IGS combined real-time products. After the combined products are made available, real-time PPP are performed for a large number of reference stations which may or may not be involved in the clock estimation.

In the PPP processing, original observables of carrier-phases and pseudo-ranges are employed with slant ionospheric delays as parameters constrained according to the a priori knowledge including an ionospheric model, and its spatial and temporal characteristics. These constraints can be expressed as:

$$
\begin{aligned}
& I_{r,t}^{s} - I_{r,t-1}^{s} = w_t, w_t \sim N(0, \sigma_{wt}^2) \\
& vI_r^s = I_r^s / f_{r,IPP}^s = a_0 + a_1 dL + a_2 dL^2 + a_3 dB + a_4 dB^2, \sigma_{vI}^2 \qquad (1) \\
& \tilde{I}_r^s = I_r^s, \sigma_{\tilde{I}}^2
\end{aligned}
$$

where, I_r^s is the slant ionospheric delay; t is the current epoch; t-1 is the previous epoch; w_t is the ionospheric change from previous epoch to current epoch; σ_{wt}^2 is the variance of w_t. vI_r^s is the vertical ionospheric delay; $f^s_{r,IPP}$ is the mapping factor (Schaer et al., 1999) at the ionospheric pierce point (IPP); the coefficients a_i (i=0,1,2,3,4) describe the planar trend; dL, dB the longitude and latitude difference between the ionospheric pierce point and the location of station, respectively.

Then the UPDs are estimated from the ambiguities of the PPP results in real-time and broadcasted at a certain update rate. Assume we have a network with n stations tracking m satellites, the undifferenced (UD) float ambiguities at each station are estimated as $\mathbf{B}_i$, we have the observation equation in the form of Equ (2) for these ambiguities.

$$
\begin{bmatrix} \mathbf{B}_1 \\ \mathbf{B}_2 \\ \vdots \\ \vdots \\ \mathbf{B}_n \end{bmatrix} = \begin{bmatrix} \mathbf{I} & & & & \mathbf{R}_1 & \mathbf{S}_1 \\ & \mathbf{I} & \mathbf{0} & & \mathbf{R}_2 & \mathbf{S}_2 \\ & & \vdots & & & \\ & \mathbf{0} & \mathbf{I} & & & \\ & & & \mathbf{I} & \mathbf{R}_n & \mathbf{S}_n \end{bmatrix} \begin{bmatrix} \mathbf{N}_1 \\ \mathbf{N}_2 \\ \vdots \\ \mathbf{N}_n \\ \mathbf{b}_r \\ \mathbf{b}^s \end{bmatrix} \qquad (2)
$$

where $\mathbf{N}_i$ is integer ambiguities, $\mathbf{b}_r$ and $\mathbf{b}^s$ are UPDs for receiver and satellites.

Assume the receiver UPD at the first arbitrarily selected station is zero, then the nearest integers of UD ambiguities at this station are their integer ambiguities and fractional parts are estimates of related satellite UPDs. Applying these UPDs to the common satellites of next station, the corrected UD ambiguities should have very similar fractional part. The mean fractional parts of all the common satellites give a estimate of the receiver UPD. With this UPD, UPDs of the satellite newly appearing at the station can be estimated. Repeating this procedure for all stations, we can have the UPDs for all receivers and satellites. After correcting the UD ambiguities with the UPDs, ambiguity-fixing can be attempted. Replacing integer ambiguities with their fixed values in Equ (2), the remaining parameters can be estimated and the UPD estimates are surely improved and will help to resolve more integer ambiguities. The above procedure can be done iteratively until no more ambiguities can be fixed. The UPDs of the previous epoch can be used as initial values of the current epoch to avoid possible jumps of one cycle.

Validation

The algorithm is developed and running operationally for IGS combined products provided by BKG using Kalman filter and by ESOC least square adjustment for validation and demonstration. Figure 1 typically illustrates the epoch-wise UPD values and the corresponding number of stations contributed to UPD values (blue for wide-lane (WL) and red for narrow-lane (NL)) based on the original observations (left) and the ionosphere-free combination (right).

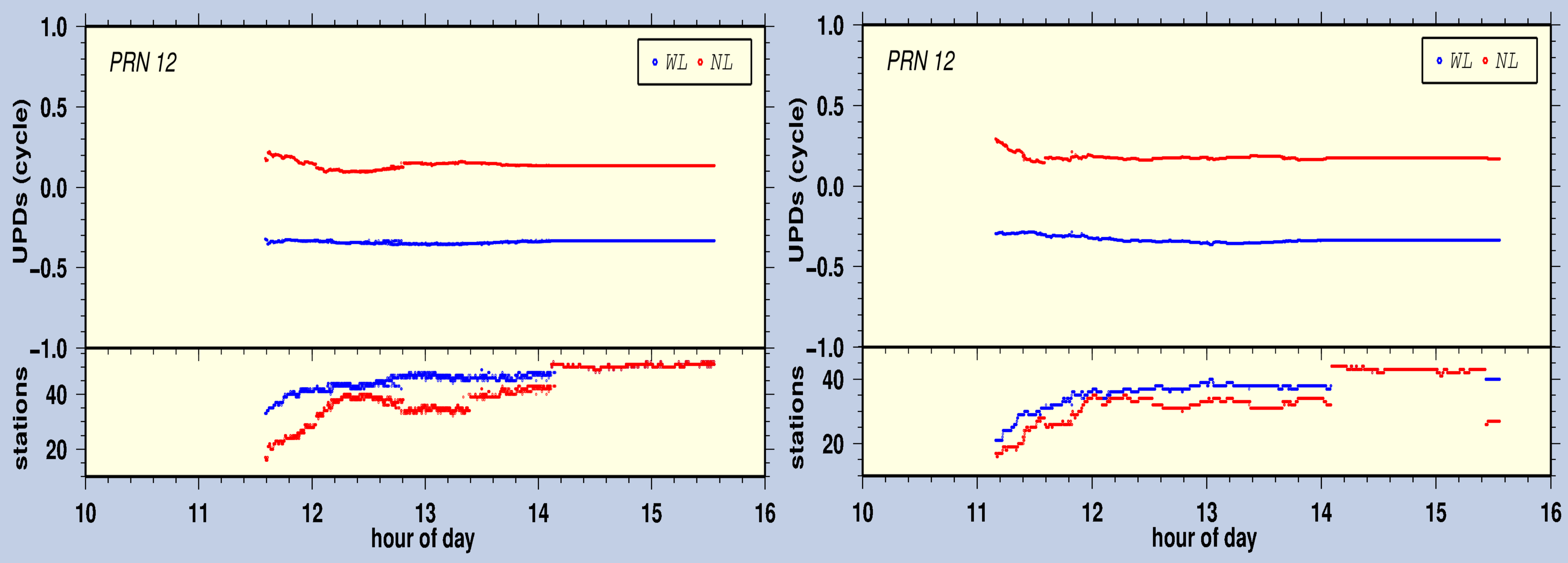

Fig. 1. Real-time UPDs based on original obs (left sub-figure) and iono-free comb (right sub-figure)

PPP ambiguity-fixing with IGS official products and the generated UPDs are carried out with a number of IGS real-time stations and the position time series are shown online at http://kg6-dmz.gfz-potsdam.de/rtgnss/ . The results of STAS and TERU are typical shown in Figure 2.

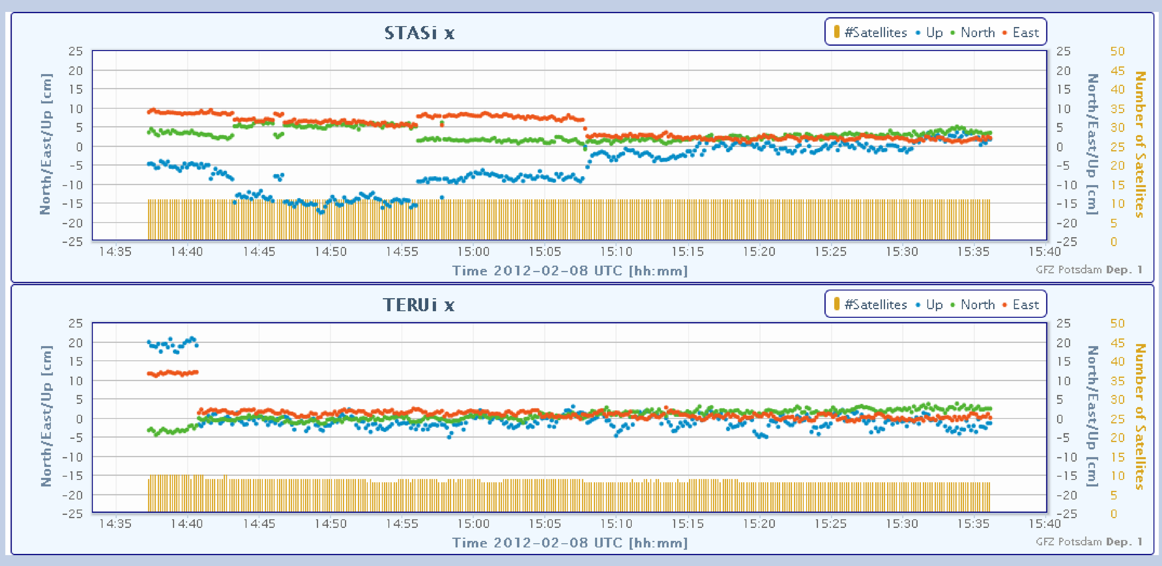

Fig. 2. STAS and TERU, PPP ambiguity fixing with IGS orbit, clock and corresponding UPDs

Fig. 3 shows the distribution of the observational time needed for the ambiguity fixing of PPP with original observations and the ionosphere-free combination. The new PPP approach reduces fixing time from 22 min to 15 min.

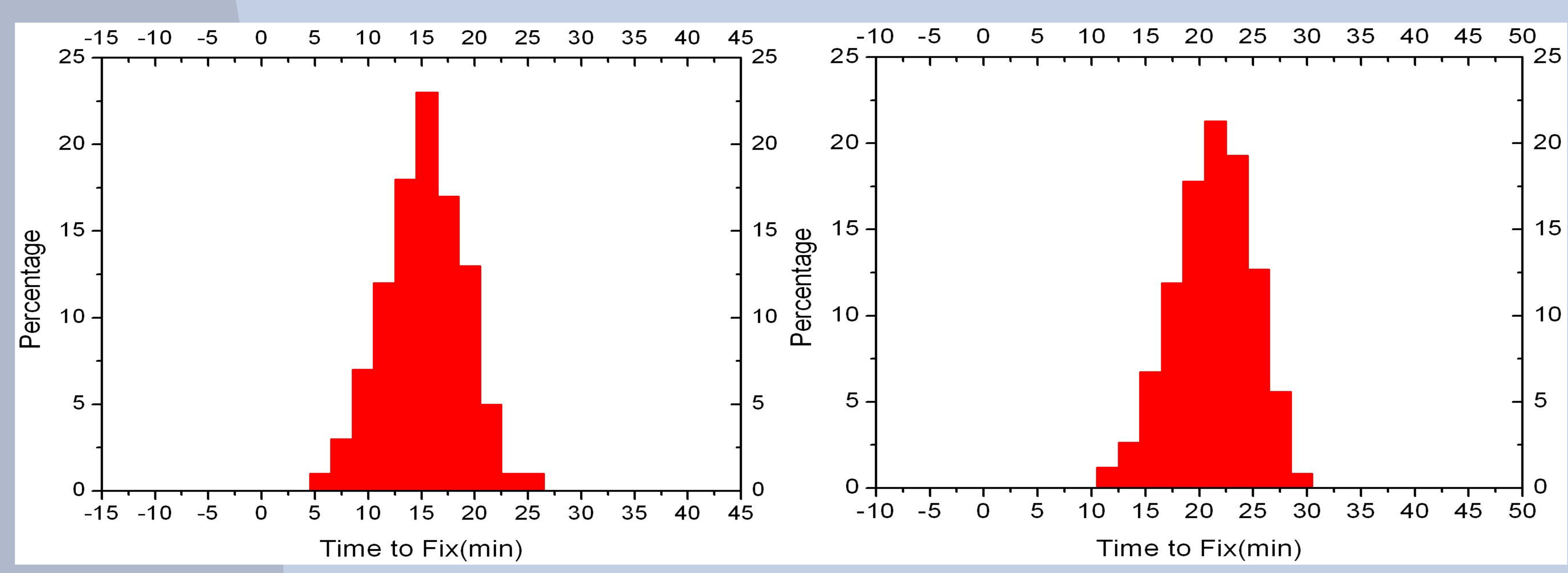

Fig. 3. Obs time needed for ambiguity-fixing of the original-obs method (left sub-figure) and iono-free method (right sub-figure)

Conclusion

The results confirm that the proposed strategy can efficiently generate reasonable UPDs for the IGS combined real-time products to enhance the official real-time PPP service by means of ambiguity resolution.

References

Ge M, Gendt G, Rothacher M, Shi C, Liu J (2008) Resolution of GPS carrier-phase ambiguities in precise point positioning(PPP) with daily observations. Journal of Geodesy, 2008

Geng J, Meng X, Dodson AH, Teferle FN (2010) Integer ambiguity resolution in precise point positioning: Method comparion. Journal of Geodesy, 2010

Li X, Zhang X (2012) Improving the Estimation of Uncalibrated Fractional Phase Offsets for PPP Ambiguity Resolution, Journal of Navigation, 2012