COMBINATION OF GPS AND GLONASS IN PPP ALGORITHMS AND ITS EFFECT ON SITE COORDINATES DETERMINATION

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ABSTRACT. Precise Point Positioning (PPP) approach using the un-differenced code and phase GPS observations, precise orbits and satellite clocks is an important alternative to the analyses based on double differences. We examine the extension of the PPP method by introducing the GLONASS satellites into the processing algorithms. The procedures are demonstrated on the software package ABSOLUTE developed at the Slovak University of Technology. Partial results, like ambiguities and receiver clocks obtained from separate solutions of the two GNSS are mutually compared. Finally, the coordinate time series from combination of GPS and GLONASS observations are compared with GPS-only solutions.

1. INTRODUCTION

The PPP processing enables direct determination of geocentric coordinates using the Global Navigation Satellite System (GNSS) observations without necessity of connection to reference stations. The attachment to the geocentric reference frame is achieved by application of precise satellite orbits and satellite clocks provided by IGS. Principal information about PPP is given by Kouba and Heroux (2001). The necessary reduction procedures and adjustment algorithms were developed for GPS observations. As the European Space Operation Centre (ESOC) produces besides GPS based data also orbits and clocks for GLONASS there is a chance to modify the PPP procedures also for other GNSS. The aim of this paper is to demonstrate experiences from introducing GLONASS into the PPP processing scheme and to discuss some partial result. The final effect of inclusion of GLONASS will be examined by inspection of geocentric coordinates. Coordinates obtained by application of the PPP software ABSOLUTE will be compared to products estimated by Bernese GPS Software Version 5.0 (Dach et al., 2007).

2. ADJUSTMENT STRATEGY

Principal steps of processing of GPS and GLONASS in the ABSOLUTE software package are: (1) Pre-processing of continuous simultaneous dual frequency phase and code observations resulting in the iono-free pseudoranges and approximate real valued phase ambiguities. (2) Interpolation of precise orbits and satellite clocks. (3) Reduction of observed ranges for systematic phenomena and computation of $o-c$ (observed minus calculated) values. (4) Forming of adjustment model and estimation of site coordinates, receiver clocks, corrections to approximate ambiguities, troposphere zenith delays and other optional parameters. Processing starts with iterative separate GPS and GLONASS adjustment and is followed by the combination of observations from both GNSS in one batch. In the ABSOLUTE software package we applied models for following range corrections: satellite clocks offsets, special relativity effect, satellite antenna offsets and differential code biases, Sagnac effect due to Earth rotation, troposphere correction, site displacement due to solid Earth tides, effects of sub-daily polar motion, Earth rotation variations and receiver antenna offsets. The theoretical background for the utilized reductions is given e.g. in (Kouba and Heroux, 2001) and (Xu, 2007). The main differences in PPP processing of GPS and GLONASS are: (1) Different orbital parameter, (2) Different signal modulations, (3) Carrier frequencies: GPS unique for all satellites, GLONASS satellite dependent. (4) Used GNSS receiver code observables: GPS C/A and P2, GLONASS P1 and P2. (5) Maximum number of operational satellites: GPS 31, GLONASS 21.

3. EXPERIMENTAL RESULTS

We will demonstrate some results related to the GPS and GLONASS PPP processing on the basis of the one-month interval (DOY 001-DOY 031 of 2010) of 24-hour sessions at the IGS and EUREF GNSS permanent station Ganovce (GANP), Slovakia, equipped with Trimble NETR8 receiver. The accuracy of L3 ambiguities resolution obtained in the first step of processing is shown in Fig. 1a. We emphasize that no orbit or clock information was used in this case and the RMS errors reflect the internal consistency of code and phase observations. The generally larger uncertainties for GLONASS are clearly visible. Fig. 1b shows independent GPS and GLONASS receiver clock estimates. Besides the constant bias of 240 ns between the two solutions we point to the sub-daily variability of their difference. Finally, in Fig. 1c are shown RMS residuals of phase observations for GPS and GLONASS estimated from one-month interval of PPP processing. It is evident that the GLONASS values are more variable than the GPS ones, especially the GLONASS PRN 7, 14 and 15 systematically manifest extremely large phase residuals. Time series of coordinate estimates of one-month period of 24-hour PPP solutions resulting from ABSOLUTE application for GPS-only and for GPS+GLONASS are in Fig. 2. The Bernese software based PPP solutions restricted to GPS observations are shown for comparison. The introduction of GLONASS into the combined adjustment decreased the coordinate repeatability.

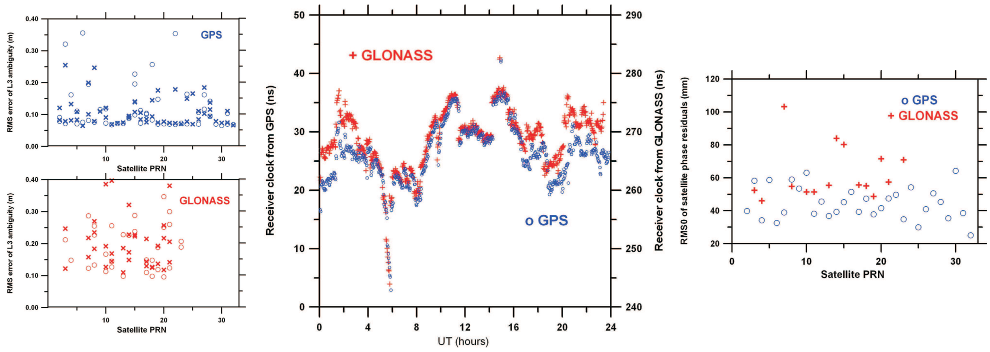

Figure 1: a) RMS errors of L3 ambiguities estimates, x-DOY 002, o-DOY 028 (left), b) Receiver clock estimates (middle), c) RMS phase residuals (right).

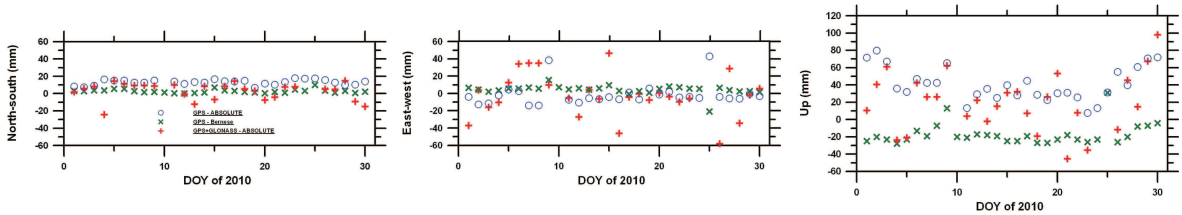

Figure 2: Local coordinate variations from PPP solutions using ABSOLUTE and the Bernese software

4. CONCLUSIONS

We demonstrated the possibilities and limitations of inclusion of GLONASS into the PPP processing. The GLONASS observations, ESOC GLONASS orbits and satellite clocks are suitable for PPP positioning. However, the accuracy of GLONASS phase and code observations as well as the reduction process yields less stabile $o - c$ values and does not improve the GPS-only PPP adjustment. The possibilities of enhancement the models for application of GLONASS in PPP are in progress.

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5. REFERENCES

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