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GLONASS inter-frequency code biases and PPP carrier-phase ambiguity resolution

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Introduction

The two fully operational GNSS GPS and GLONASS use different methods to make their signals distinguishable. GPS satellites broadcast their signals on the same frequencies but with different PRN codes (code division multiple access, CDMA). On the other hand, GLONASS satellites transmit their signals with the same PRN code but on slightly different frequencies in the two parts of the L-band (frequency division multiple access, FDMA).

Due to FDMA, GLONASS signals experience different code delays in the receiving equipment which affect both, the code positioning solutions and those ambiguity resolution techniques which rely on the code measurements. Although, the carrier-phase is also affected, but modelling and correction of the carrier-phase inter-frequency bias (IFB) seems to be easier than the modelling and the correction of the code IFB or of a combined carrier-phase/code IFB.

As a consequence, difficulties occur in Precise Point Positioning (PPP) ambiguity resolution (AR) where the Melbourne-Wübbena (MW) linear combination (LC) is used for fixing the widelane (WL) ambiguities. We have tested pure carrier-phase WL AR as an alternative technique.

Precise Point Positioning (PPP) Ambiguity Resolution (AR)

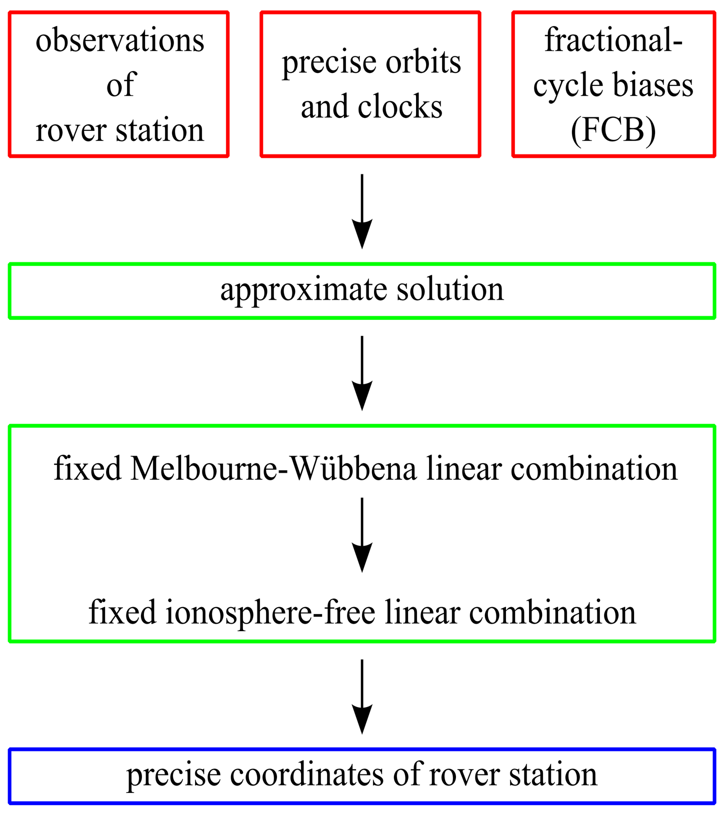

Fig. 1a: PPP with Melbourne-Wübbena linear combination

PPP AR requires orbit and clock corrections (e.g. from IGS AC ESOC, Darmstadt, Germany) and fractional-cycle biases (FCB).

PPP AR is based on a 2-step fixing algorithm. Usually, the first step involves the MW LC to resolve WL ambiguities (Fig. 1a). This combination of carrier-phase and code has the advantage that it is not affected by the atmosphere, orbit and clock errors. However, the signal delays are a combination of the delays from carrier-phase and code.

As an alternative approach to fix WL ambiguities, a pure carrier-phase WL AR can be used (Fig. 1b). Here, code observations are not directly involved and thus the frequency-dependent code delays do not affect this method. This approach, however, is affected by many other kinds of GNSS errors, with ionospheric refraction being the most prominent one. Hence, ionospheric corrections are required. Of course, the IFB of the carrier-phase has also an impact.

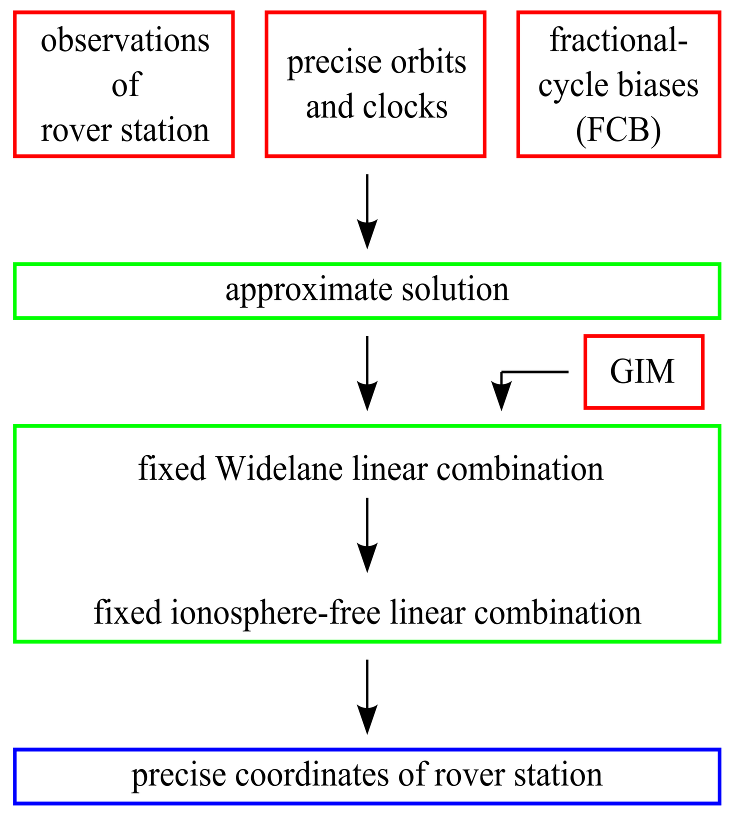

Fig. 1b: PPP with widelane linear combination

GLONASS Code Delays

One of the reasons for the introduction of code observations into PPP is the use of the MW AR technique.

As shown by mean code residuals of the ionosphere-free LC P0 of 2 weeks of observations from 2010 and from GREF (Integrated Geodetic Reference Network of Germany) and EUREF stations, a dependence on frequency is obvious. Moreover, these delays are receiver-individual and antenna-individual (Fig. 2a).

In addition, the code delays can behave completely different after an antenna exchange as shown by the mean P0 code delays from station ERLA with each panel of Fig. 2b being based on 1 week of observations from 2010.

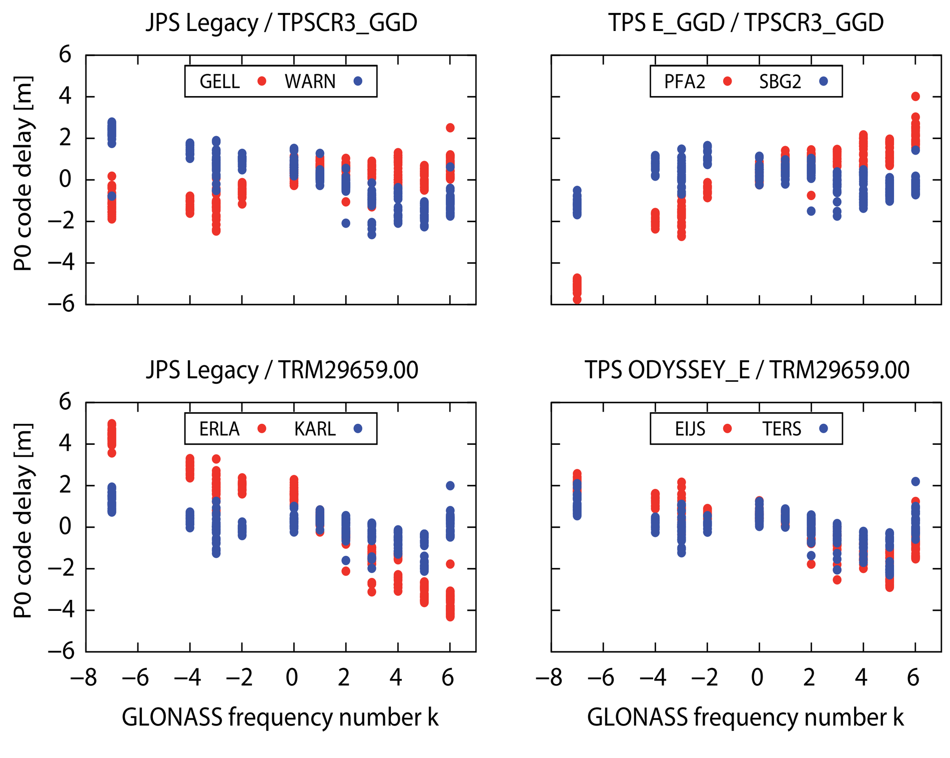

Fig. 2a: Mean GLONASS ionosphere-free code delays for 8 GREF and EUREF stations with 4 different receiver/antenna combinations

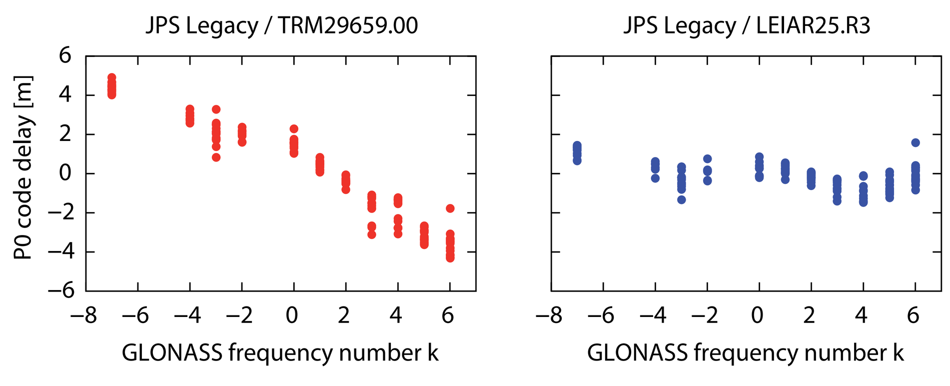

Fig. 2b: Mean GLONASS ionosphere-free code delays for station ERLA before (left) and after (right) an antenna exchange

GLONASS MW Ambiguity Resolution

As shown in Fig. 2a and 2b, it can be expected that the MW LC is biased by code delays which may be able to prevent a successful MW AR. Therefore we analyzed the fractional parts (FP) of WL ambiguity estimates using the MW LC.

First, we calculated MW FP for station WARN based on 2 weeks of observations from 2010 (Fig. 3a). The applied FCB were estimated from observations of station BORJ. Both stations are equipped with JPS Legacy receivers and antennas of type TPSCR3_GGD. The characteristic of the P0 code delays of WARN and BORJ is very similar. Nevertheless, a frequency dependence is visible in the MW FP (left panel of Fig. 3a). The main part of the frequency dependence can be removed by linear modelling. Large residual errors remain for channel number k = -7 (R10 and R14) and prevent a successful AR.

Secondly, we calculated MW FP for station ERLA with the same data as used for Fig. 2b (Fig. 3b). The applied FCB were estimated from observations of station PFA2. It is clearly noticeable, that an antenna exchange can cause a shift of the MW IFB.

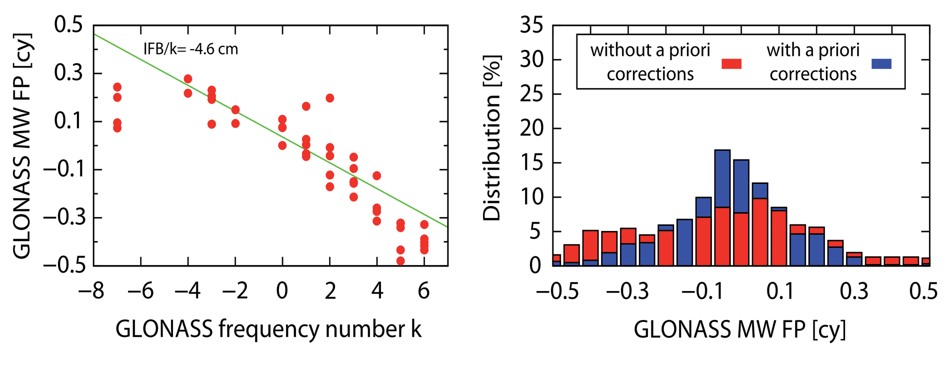

Fig. 3a: Fractional parts of PPP ambiguity estimates using the Melbourne-Wübbena linear combination for station WARN

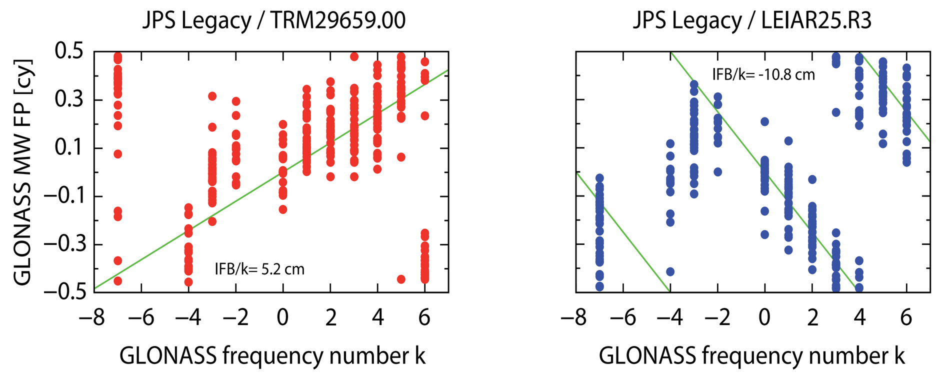

Fig. 3b: Fractional parts of PPP ambiguity estimates using the Melbourne-Wübbena linear combination for station ERLA

GLONASS WL Ambiguity Resolution

The WL AR based on pure carrier-phase is an alternative technique to the MW AR. WL AR is not influenced by code biases, but by other kinds of GNSS errors which may be able to prevent a successful WL AR.

Based on observations of 6 consecutive weeks from 2010 and from 11 GREF and EUREF stations, we calculated GPS MW FP, GPS WL FP and GLONASS WL FP after applying MW and WL FCB.

In the case of GLONASS, we distinguished 2 approaches: no application of a priori WL IFB, application of correction values published by Wanninger 2012 (Journal of Geodesy, 86:139-148).

Fig. 4a shows the distribution of GPS MW and WL FP. A fixing efficiency of 95 % and 86 % can be reached for GPS MW and GPS WL ambiguities, respectively (round-off criterion: 0.2 cy).

Fig. 4b shows the distribution of GLONASS WL FP. Without application of WL IFB, they are much larger than the ones of GPS. After applying WL IFB, a fixing efficiency of 82 % for GLONASS WL ambiguities can be reached (round-off criterion: 0.2 cy). The GLONASS WL results are almost as good as the ones of GPS WL.

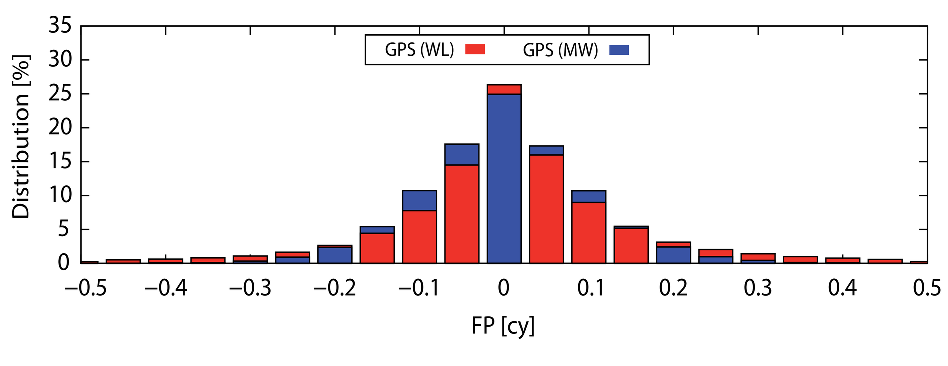

Fig. 4a: Distribution of the fractional parts of GPS PPP ambiguity estimates

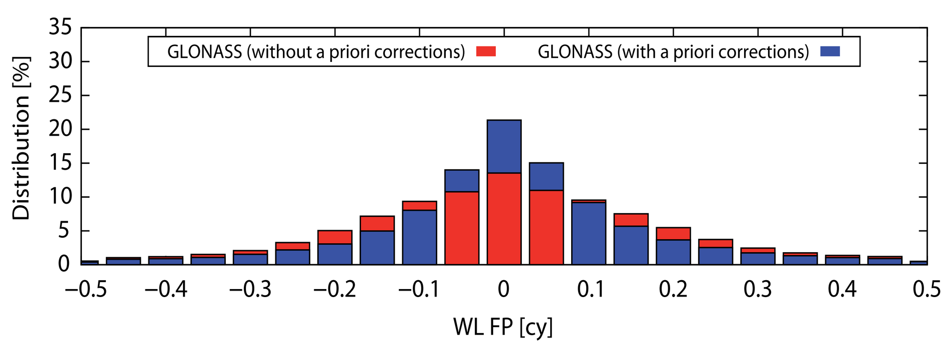

Fig. 4b: Distribution of the fractional parts of GLONASS PPP ambiguity estimates of the carrier-phase widelane linear combination

Summary

As a consequence of the GLONASS FDMA approach, receiver/antenna hardware biases are not equal for all signals, but they depend on the signal's frequency and they are different for carrier-phase and code. Furthermore, code delays are receiver- and antenna-individual so that antenna exchanges can cause shifts of the MW IFB. GLONASS code delays are often so large that they complicate MW AR.

The modelling and correction of the pure carrier-phase IFB is easier than the modelling and correction of the code IFB or a combined carrier-phase/code IFB. Therefore, WL AR based on the pure carrier-phase is an alternative technique. After applying a priori correction values of the GLONASS WL IFB, the fixing rate of GLONASS WL ambiguities is not as good as the one of GPS MW ambiguities but still acceptable.

In conclusion, we propose to use Melbourne-Wübbena widelane ambiguity resolution for GPS and pure carrier-phase widelane ambiguity resolution for GLONASS.

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