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Assessing the ambiguity time convergence as function of constraints in the station coordinates and vice versa.

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Abstract

Nowadays, one of the main research topic on GNSS positioning is PPP ambiguity resolution (PPP-AR) as well as the ambiguity convergence (PPP-AC) time required to reach some level of accuracy. Several papers have been published concerning PPP-AR. In this contribution the aim is to answer the following questions in the context of PPP: a) Once you know the position of one station how long should take to reach accuracy of the ambiguities in the level of at least 1/3 of a cycle (~6cm); b) Once you know the ambiguity with this level of precision, how long should take to obtain a position with 3D- precision better than 10 cm. In a first case, we will use the ion-free observable, so without a priori knowing about the ionosphere and estimating the troposphere residuals after applying an appropriated model. In the second case, we will assess the original observables and include the ionosphere delay for each satellite to be estimated in the model, assuming or not some knowledge about the a priori ionosphere delay. In both cases, the receiver clock errors are treated as white noise. All other effects such as Earth tides, ocean tide loading, antenna phase center corrections, phase wind up, phase center bias (PCB) and DCB (Differential code bias) should have been taken into account. Mathematical fundamental and results from data under different atmosphere conditions will be presented.

Real time PPP

- Real time PPP (RT-PPP) is the state of the art for positioning. The main observables are the pseudorange and carrier phase, either the ion-free or the original one (undifferenced). Therefore, in the former, the 1st order ionosphere is correct for, without the possibility of applying any information available about the ionosphere, what is possible for the last one.
- With the IGS Real Time Pilot Project (IGS-RT) the approach now is available free of charge to the users. IGS-RT provides several products and the corrections to the broadcast ephemeris and clocks are the main one to be used in the development of this work.
- The main concerns about PPP is related to the time of ambiguities convergence and consequently, the required interval to reach an expected level of accuracy, like 10 cm for example.
- Our concerning is about the time convergence of the ambiguities when the coordinates of the network (station) are known to certain level of quality (for example 10 m to 0,02 m). And once the ambiguities are known (fixed or with precision in the level of ~6cm) with level of coordinates precision is feasible of being obtained.
- GNSS data processing were carried out using two systems: BNC PPP and Wizzard PPP.

Real time PPP using BNC

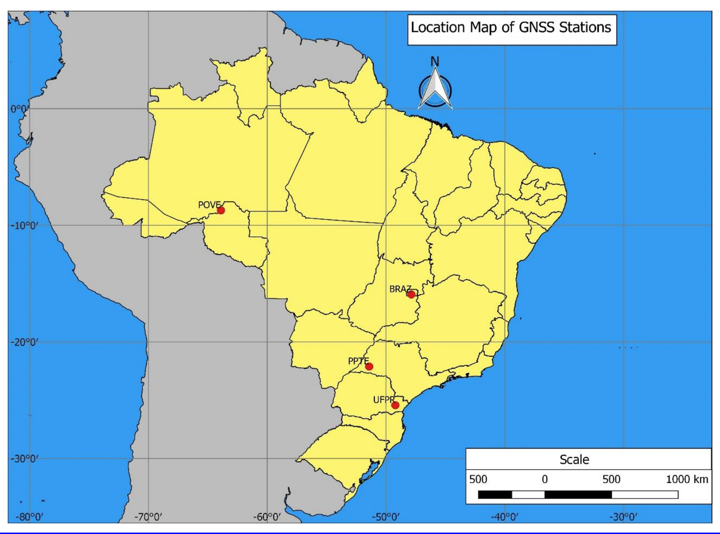
- BNC (BKG NTRIP Client) was developed by IAG sub-commission for Europe and IGS. It has been created for retrieving, decoding, converting and processing or analyzing real-time GNSS data streams, simultaneously, using NTRIP. RT-PPP can be performed on BNC by processing GNSS data from a receiver connected to the program or by data sent by a GNSS station via NTRIP. In the processing, corrections of orbits and satellite clocks errors must be applied, which are made available by IGS analysis centers. The fundamental observables are the ION-FREE, P3 and P3&L3.
- Additionally, some corrections are applied: Phase wind up, Solid Earth Tide and Receiver Antenna Offset. For the troposphere, the a-priori values are given by Saastamoinem model, and a residual part is estimated. BNC provides ambiguities as float.

Real time PPP using Wizard

- The PPP-Wizard provided by CNES contains the PPP implementation with AR. Details about about concepts, models etc., can be found in (Laurichesse and Privat, 2015). This open-source implementation is provided by the on-line PPP-Wizard demonstrator.
- It shows real-time results for stations worldwide, demonstrating cm accuracy-level performances. The demonstrator has three main parts. The first is the SSR parameters computation (orbit, clock and biases). To generate such products, a global network of real-time GNSS stations is used. The second part is the transmission of the network SSR parameters, which are provided freely by CNES for non-commercial purposes. The open-source PPP package is the third part, which is the user side.

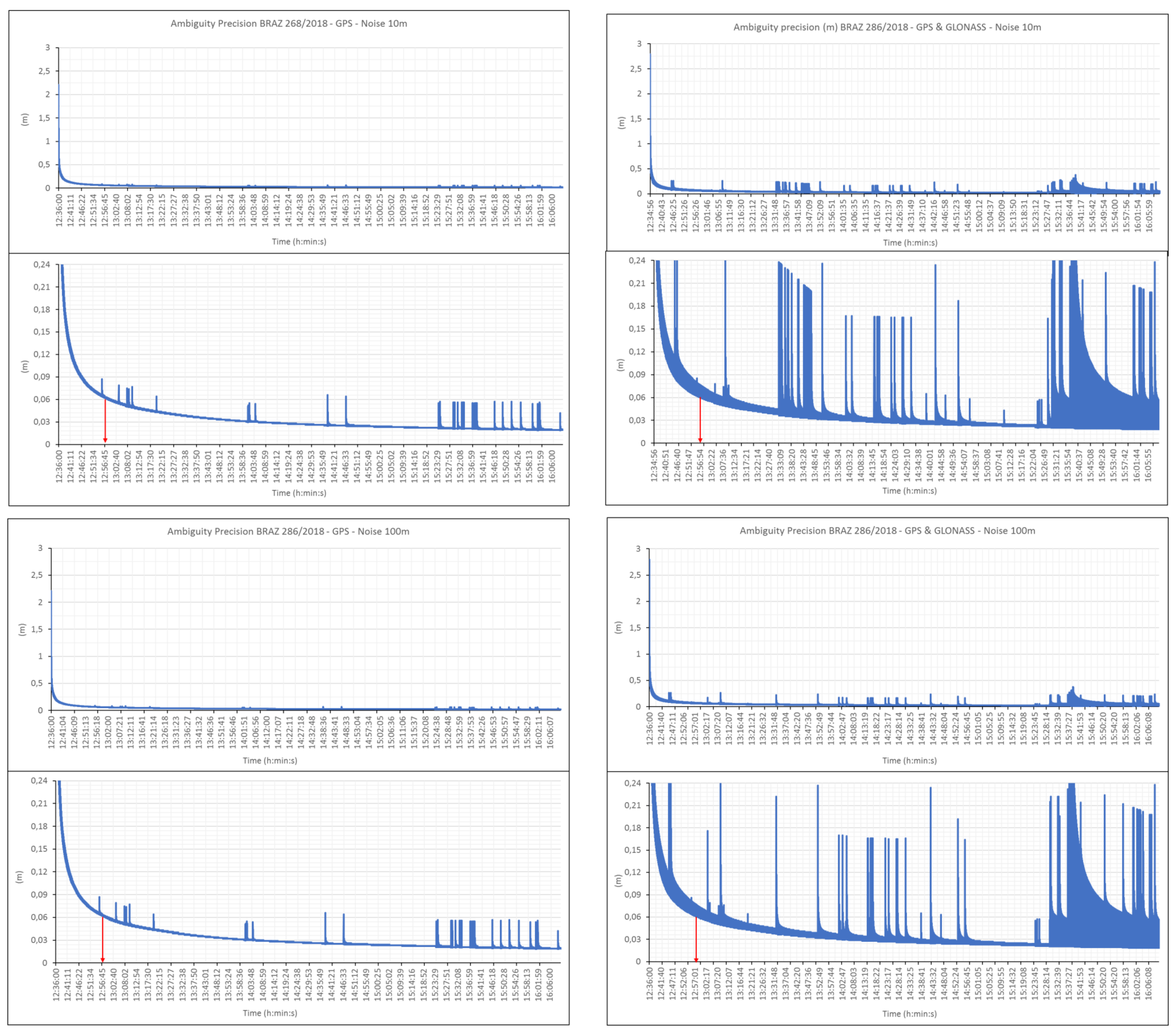
Data Selected for processing

- For data processing, four stations were selected, which provide data via NTRIP. They are POVE, BRAZ, PPTE and UFPR and are showed in the figure below. Several sections of processing were carried out during two days with different time spam, depending of availability of internet and data. Only GPS and GPS & GLONASS were considered.
- The known coordinates were kept constrained to 2cm for about 2 minutes and them a noise of 10 or 100 m was applied, characterizing a kind of kinematic data processing.
- For troposphere, Saastamoinem model was applied with sigma of 0,01 m per hour.

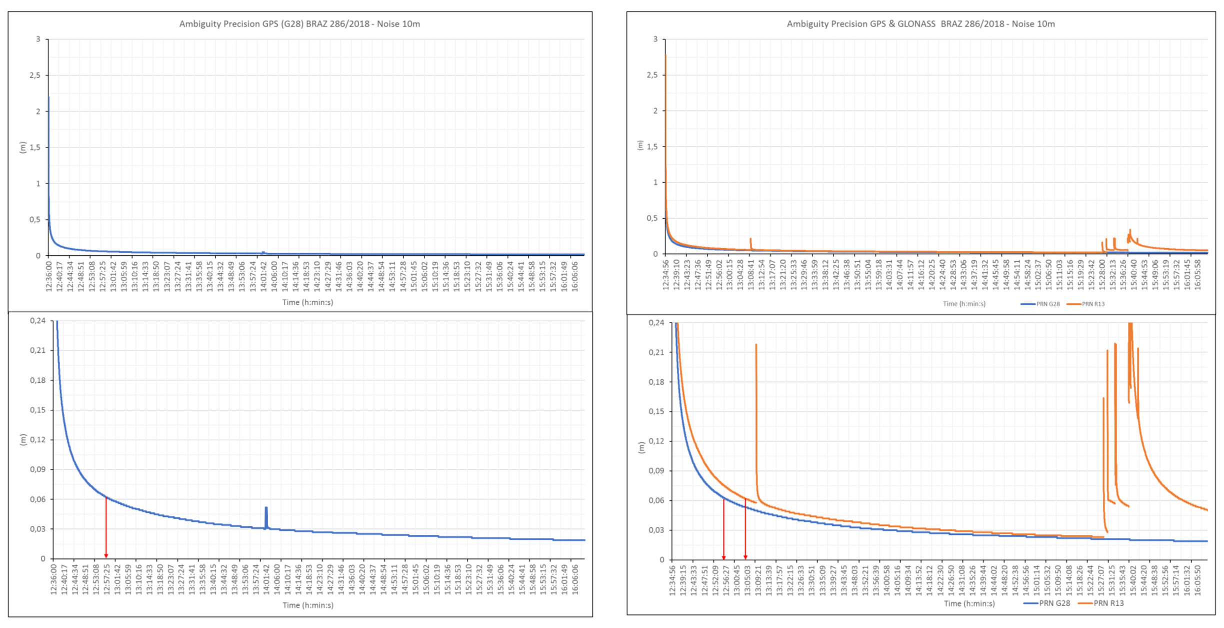


Ambiguity time convergence as function of coordinates constraints (PPP-BNC)

- Two main tests were carried out so far. Coordinates (E, N and UP) constrained to 2 cm during 2 minutes and then a noise of 10 m or 100 m was considered for each component.
- We can observe, from station BRAZ, that using GPS or GPS & GLONASS is not so important for improving the precision of the ambiguities during time. The same could be observed for the other stations. To reach the level of about 6cm, it took at least 20 min (see red line). We also tested the coordinate constrained during 5 minutes, and no significant time reduction was observed in the convergence.

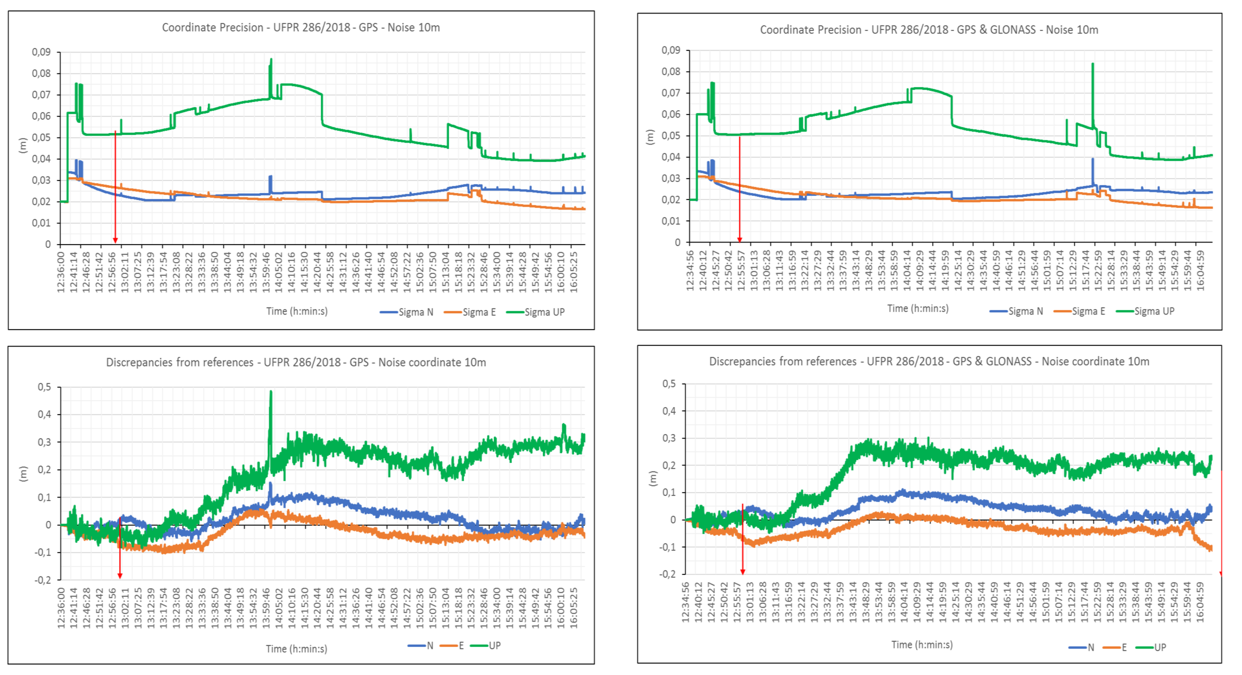


- The peaks that we can observe in the figures are mainly due to the fact of satellites starting been tracked, or recovered of tracking loss. See figure below. PRN G28 and PRN R13 recorded data in the time interval shown in the two figures below. One can observe that the ambiguity precision for PRN R13 was always worse than that of PRN G28. In these figures we can also visualize that the GPS satellite (G28) had more continuity than the GLONASS one, which had several reinitializations or cycle slips.



Coordinates (E, N and UP) precision as function of ambiguities precision (from 6 cm). (BNC)

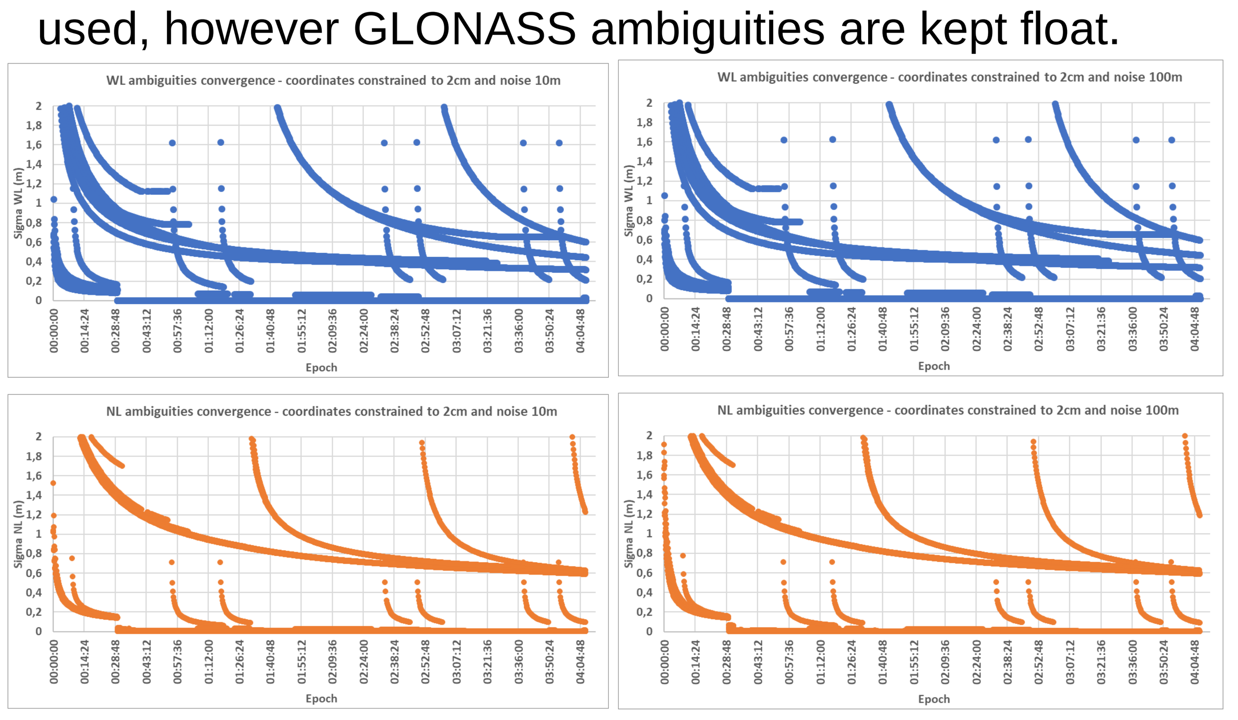
- Here the aim is to observe the convergence time of the coordinates as function of the ambiguity precision. The next 04 figures show the coordinates precision and biases as function of time once the ambiguities reach a level of precision of about 6 cm (red line).



- From these figures one can observe that the precision of the coordinates are always better than 10 cm once the noise is introduced (after 2 min initialization). And if it is 10 or 100 m is not so important (not shown in the figures).
- Concerning the biases between the reference (SIR17P01) and the estimated coordinates, we cannot see significant improvement once the ambiguities reach ~ 6 cm. The behavior is approximately the same since the beginning. The N and E components are always better than 10cm, but UP is worse than 20 cm most of the time. Similar results were obtained for all stations.

Ambiguity time convergence as function of coordinates constraints (PPP-Wizard)

- Figures below for WL and NL ambiguities convergence with PPP-Wizard. First epoch coordinates constrained to 2cm are assessed at UFPR (00h-DoY 285/2018), with noise kept as 10m and 100m. GPS+GLONAS data are used, however GLONASS ambiguities are kept float.



- The gains with the use of known coordinates are observed especially in the first epochs. Ambiguities converge slightly faster when noise of 10m is employed.

Coordinates convergence as function of ambiguities constraints (PPP-Wizard)

- Next we see coordinates precisions and discrepancies, considering both cases, 2cm constraints are used in the first epoch with 10m and 100m as noise in the others.

- Concerning the positioning convergence, constraints effects are quite visible, in terms of precisions and discrepancies wrt reference coordinates. A considerable bias was also found, especially for the N component, requiring further investigations.