Evaluation of Analysis Options for GLONASS Observations in Regional GNSS Networks

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Abstract. The declaration of the Russian President Vladimir Putin on completing the GLONASS 24 satellite constellation until end of 2009 revitalized the activities in the geodetic world to make use of that satellite navigation system. There are today various combined GPS/GLONASS receivers operating at permanent reference stations, corresponding observation files are stored in public data archives, and also analysis software exists. But the introduction of GLONASS observations into regional GPS permanent networks, e.g., one of the sub-networks of the EUREF GPS Permanent Network, could not satisfactorily demonstrate any benefit from this approach. Therefore potential analysis options for GLONASS observations has been evaluated in a test analysis of only a few selected sites. The test scenario considers especially the fact of the un-complete GLONASS satellite constellation and the mixture of GPS and combined GPS/GLONASS receivers in the network. This study confirms that only sporadic improvements of regional network station coordinates could be expected when adding GLONASS observations today, but this may change in future.

Keywords. Regional Networks, GLONASS, GNSS

1 Introduction

This study aims to show up the development from the single GPS navigation system to a multi Global Navigation Satellite System (GNSS). There exist many perspectives inside and outside geodesy concerning questions around that subject. We focus here on the precisely determination of station coordinates in the scope of geodetic applications, and thus our accuracy requirement is better than 1 cm. This requirement separates the effort from simple positioning and comparable application schemes. Furthermore we restrict this evaluation to static ground station coordinates from the total quantity of geodetic relevant parameters. Such we don’t investigate, e.g., the effect of an extended satellite constellation on ionosphere or troposphere modeling.

The effect of adding a second satellite navigation system to GPS will be evaluated by GPS and GLONASS combinations. The combined GPS and GLONASS satellite constellation represents a future GNSS. The declaration of the Russian President Vladimir Putin in 2006 on completing the GLONASS 24 satellite constellation until end of 2009 (Moscow Times, August 2006) revitalized the activities in the geodetic world to make use of that satellite navigation system. The current constellation of 16 GLONASS satellites in space and the existence of globally distributed and permanently tracking combined GPS/GLONASS receivers allow a realistic GNSS positioning. Observation data in the scale of regional network stations will be analyzed within this study.

The GPS to GNSS development concept will be described in the following chapter and shows the principles to extend GPS to GLONASS, which includes the upgrade of the satellite constellation as well as the ground station tracking equipment. A pilot study for evaluation of the best suitable analysis options will be carried out prior analyzing a test network with various satellite constellations.

For the interpretation of the results it must be considered that we have an un-complete GLONASS satellite and GNSS receiver constellation today. Completed constellations may improve all results in the future. It is planned to extend this study in the future by accounting the European Galileo system.

2 GPS to GNSS Development Concept

The basic concept of this study considers variations in three domains that are applied to demonstrate the extension of GPS to GNSS:

- Variation of strategic analysis options,
- Variation of satellite constellation,
- Variation of receiver constellation.
The variation of strategic analysis options depends importantly from the basic observable. We use the double difference phase observable in the numerical part of this study. All conclusions for analysis options has to be viewed within this context.

The development of the satellite and receiver constellation domains are shown in Figure 1. There are three different ways for augmentation if you start from the GPS satellite and receiver constellation to reach the GNSS constellation, which is given as “GPS + GLONASS” in the figure. Starting point is always the GPS stand-alone situation as marked as “S0”. The first way deploys the full GLONASS satellite constellation at the beginning, before any receiver at the ground starts tracking a GLONASS signal (shown in red in the figure). This is only a theoretical way that already has been overcome today. The second way deploys all ground tracking stations with combined GPS/GLONASS receivers, before start tracking as many GLONASS satellites as are in orbit. This alternative is labeled “S1” and shown in blue. The third way starts immediately to track all available GLONASS satellites in space from the currently installed combined GPS/GLONASS ground station receivers. This way is labeled “S2” and shows up in black. S2 represents the real situation today.

Figure 1 points furthermore a “system axis”. We could imagine other satellite navigation systems along this axis, e.g., a GPS and Galileo combination.

2.1. Variation of Strategic Analysis Options

It is mandatory for the combination of two independent satellite navigation systems to account for all system dependent differences, e.g., system time, reference system, frequency aspects etc., but this topic will not be dealt with in this paper. It is assumed that these system biases have been corrected within a certain level. We consider here
- the level of combination, and
- the usage of analysis options.

GPS and GLONASS observations as tracked by a combined receiver type may be combined at various levels within the analysis procedures. The best practice is to consider GPS and GLONASS to be equivalent and to run the analysis in exactly the same algorithm for both satellite types. But it requires a perfect modeling of all system biases within the analysis software. The simplest combination is to determine separate station coordinates from GPS and GLONASS observations and after that to combine the coordinates. The disadvantage of such an approach is the loss of existing correlations, e.g., the troposphere refraction is independently modeled but is physically the same. There exist a couple of intermediate combination levels between the two extremes. One candidate scenario results from separate pre-processing of both, GPS and GLONASS, observations. In case of the double difference approach, as applied in all analysis of this study, the pre-processing includes the baseline selection and the phase cleaning for outliers and cycle slips. The cleaned single difference (between stations) files will be combined in the final parameter estimation.

A second candidate scenario concerns the ambiguity resolution approach that could be differently for GPS and GLONASS satellites. Results for both scenarios will be shown.

2.2. Variation of Satellite Constellation

The total number of observations increases, if the ground stations track more satellites. This requires new signals from space and ground station receivers that are capable to receive the new signals. Figure 2 shows the development process where all ground stations are capable to track GNSS signals and the number of observations increases as soon as GLONASS satellites are added to the used satellite constellation.