GNSS Data Analysis in GAPS, the GPS Analysis and Positioning Software, Using IGS Products

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1. Introduction

A PPP application developed at UNB (University of New Brunswick), called GAPS (GPS Analysis and Positioning Software), has been designed and built in order to be useful as a tool for determining various parameters in addition to position, receiver clock error, and neutral atmosphere delay. These other estimated parameters include ionospheric delays, code biases, satellite clock errors, and code multipath among others. GAPS is a veritable "Swiss Army knife" for GPS data analysis. GAPS is available for use on the Internet via a Web interface at the address http://gaps.gge.unb.ca/ .

GAPS' applications can be summarized as follows:

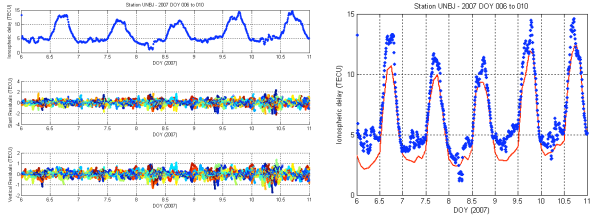
- Precise point positioning;
- Ionospheric delay estimation;
- Differential code biases estimation;
- Code noise estimation;
- Receiver/satellite clock error estimation.

Because of the variety of applications, GAPS is not only a precise point positioning tool, but a GPS analysis tool. GAPS' data processing is essentially based on a very complete error handling. This is done by means of the use of precise products (such as satellite orbits, clocks, and antenna information) and a comprehensive implementation in terms of observation modelling.

2. Application Descriptions

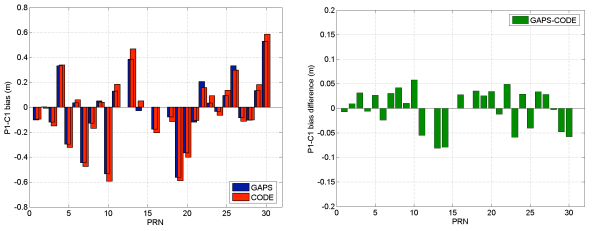
Precise point positioning (PPP) is one of the existing techniques to determine point coordinates using a GPS receiver. In this technique, observations realized by a single receiver are used in order to determine the three components of the position, as well as other parameters, such as the receiver clock error and total neutral atmosphere delay. The technique is said to be "precise" because precise information, such as satellite orbits and clock errors, is used in the data processing.

The **ionospheric delay estimation** is based on carrier-phase observations only, which are processed using a filter capable of de-correlating ambiguities and biases from the delay, in order to provide reliable estimations.



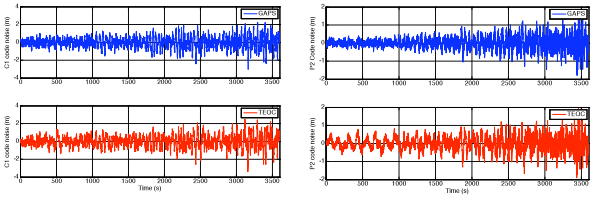
Ionospheric delay estimation for IGS station UNBJ, DOY 006-010/2007.

GAPS is capable of providing **differential code biases**, which are useful quantities when processing pseudoranges for positioning. The innovation in this approach is that these biases are estimated in a positioning-like filter (very similar to the model of the biases - positioning - user), rather than as a clock estimation by-product.



P1-C1 code biases estimation – Comparison between GAPS and CODE solutions

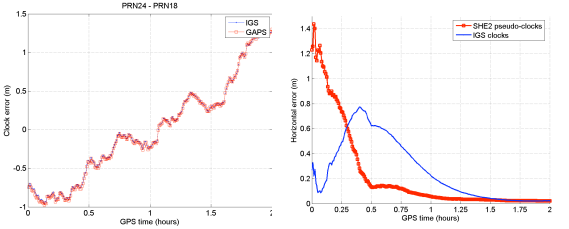
One of GAPS outputs is an estimate of **code noise**. This estimate can be used as an alternative for multipath quantification, where the uniqueness of this approach lies in the fact that the estimation doesn't rely directly on carrier-phase measurements. GAPS' code noise estimates do not provide a pure multipath quantification, but a combination of all un-modelled effects of pseudoranges when used in a high accuracy PPP solution using IGS products. Therefore these quantities are very meaningful for signal+model quality analysis. Nevertheless, the quantities are similar to ones obtained using other multipath estimation techniques (e.g. TEQC).



Code noise estimation – Comparison between GAPS and TEQC solutions (IGS station ALGO, DOY 008/2007)

Another GAPS feature is the estimation of **satellite pseudo-clocks**. The term "pseudo" is used because these estimates are highly affected by effects such as orbit error, residual neutral atmosphere delay, and multipath, among others. The pseudo-clock estimates are also biased to a certain extent when compared to IGS clock estimates, due to the fact that an approximate ambiguity is used. The use of the approximate ambiguity is possible because all bias gets absorbed by carrier-phase ambiguity when the pseudo-clock is used for positioning, and also it allows the estimation of carrier-phase-quality pseudo-clocks without the need of initialization (to achieve the convergence of estimated ambiguities if it is the case). The pseudo-clocks can be estimated with data from a single station, and can be used for positioning of other nearby receivers, offering the possibility of running a PPP engine at rover, using data from either a global network (e.g. IGS clock products) or a local infrastructure (as small as one single reference station).

In the example below, pseudo-clocks were estimated using data from IGS station SHE2, and afterwards used for positioning, with data from IGS station UNBJ. These two stations are about 164 km apart.



Pseudo-clocks estimation – Comparison between GAPS and IGS solutions (IGS stations SHE2 and UNBJ, DOY 001/2008)

3. Under Development

The current version of GAPS is written in MatLab, but the whole software is being re-designed and re-written in C++. The re-design of the software includes not only programming language issues, but also the modernization of the software for handling future GNSS observables; i.e., GPS L5, GLONASS and Galileo (the current version of GAPS already handles GPS L2C data).

The modernization of the software obviously includes handling the RINEX 3.00 data format, and UNB has put efforts into stimulating usage of the new format. Hourly data in R3.00 format from station UNB3 is being stored on the CDDIS ftp server, under:
ftp://cddis.gsfc.nasa.gov/gps/data/test/rinex3/2008/

4. Concluding remarks

In this poster, we have given an overview of GAPS capabilities for positioning and data analysis using IGS products. A comparison with IGS IONEX maps showed great potential for estimating precise un-biased ionospheric total electron count with GAPS. When using GAPS to compute code biases, the overall agreement with CODE solution is better than 4 cm, which shows that, with our PPP-based technique, we can match other bias-estimation techniques at the few cm level. When comparing our code noise estimation results with those obtained using software TEQC from UNAVCO, we found an agreement of the pseudorange noise level to better than 5 cm. When using GAPS for estimating satellite pseudo-clocks and comparing them with final IGS cocks, it was possible to find an agreement for between-satellite clock behavior of around 9 mm. When using pseudo-clocks for positioning, results show a better convergence time than using IGS clocks, and final accuracies were at about the same level for the two solutions. Overall, we have shown that GAPS is a unique software tool which can provide results of several kinds, matching or surpassing the capabilities of other pre-existing well established techniques.

5. Acknowledgements

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