GINS: THE CNES/GRGS GNSS SCIENTIFIC SOFTWARE

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ABSTRACT

The Centre National d'Etudes Spatiales (CNES) and the Groupe de Recherche de Géodésie Spatiale (GRGS) develop the multi-technique GINS software for their space geodetic activities. In preparation to the Galileo system deployment, GNSS data processing capability have been implemented. GINS performance is illustrated through 4 applications including precise orbit determination of GPS, GLONASS and GIOVE satellites and GNSS Precise Point Positioning processing.

1. INTRODUCTION

GINS is a scientific tool developed by the Centre National d'Etudes Spatiales (CNES) and the Groupe de Recherche de Géodésie Spatiale (GRGS) for more than 40 years for geodetic applications like global gravity field modelling and reference frame realization [1]. This multi-technique software is currently exploited to process any geodetic techniques like Satellite Laser Ranging (SLR), Very Long Baseline Interferometry (VLBI), DORIS, GNSS, low-low satellite-to-satellite tracking (GRACE mission), gradiometer observations (GOCE mission), and radio-science data (Deep Space Network DSN and ESA Station Tracking Network ESTRACK) for planetary studies. For example, GINS is daily operated by the Analysis Centre formed by CNES and Collecte Localisation Satellite (CLS) to deliver precise GPS and GLONASS orbit and clock products to the International GNSS Service (IGS). GINS processes zero-difference GNSS data using a unique ambiguity resolution method. It can then track an isolated GNSS receiver in a Precise Point Positioning (PPP) approach at the centimetre level. Furthermore GINS has been adapted with the aim to make the processing of GIOVE and future Galileo satellite data achievable. GINS GNSS capabilities are illustrated in the following through 4 examples: the computation of GPS and GLONASS precise IGS products within the frame of the CNES-CLS AC activities (section 2), simultaneous GIOVE and GPS satellites orbit determination (section 3), high rate PPP using GPS and GLONASS data (section 4), and kinematic Integer PPP (IPPP) (section 5). GINS is based on an iterative least squares adjustment but a Kalman filter has been recently implemented to make kinematic processing faster.

2. GPS AND GLONASS PRODUCTS

GINS software is exploited by CNES and CLS French space geodesy teams for orbit determination and Earth dynamics studies. Data from 140 GPS and GLONASS IGS stations (Fig. 1) are routinely processed. The products have been submitted to IGS [2] since September 2007 on a weekly basis. They include:

- GPS constellation orbits and clocks (900s sampling)
- GLONASS constellation orbits (900s sampling)
- GPS, GLONASS, and receivers clocks (30 s sampling)
- SINEX solutions including station coordinates and Earth Orientation Parameters (EOP)

SLR residuals are computed on both GPS and GLONASS ephemeris solutions and uncalibrated Wide-Lane phase delays are daily estimated for every GPS satellite. These so-called Wide-Lane Satellite Biases (WSB) associated with phase clocks products (available at http://igsac-cnes.cls.fr) help in solving phase ambiguities to integer values at the zero-difference level (see section 5).

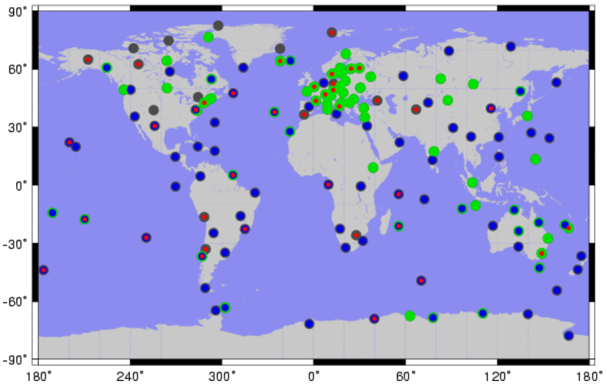

Figure 1. GPS (blue) and GLONASS (green) network

The CNES-CLS products, named GRG, are routinely evaluated by the AC Coordinator by combining them with all AC products (Jim Ray; see http://acc.igs.org). The quality of GRG GPS orbits is illustrated on Fig. 2, showing time series of Weighted RMS of individual AC orbit solutions with respect to IGS GPS final products.

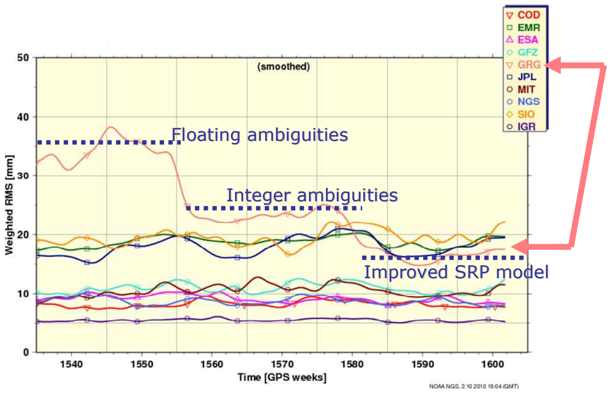

Figure 2. GRG GPS orbit evaluation (pink curve)

This figure focus on recent improvements of GPS GRG orbits. They are due to ambiguity fixing to integer values and changes in Solar Radiation Pressure models (SRP). Currently, GRG GPS orbits reach a satisfying level of consistency with other IGS AC.

The quality of GLONASS GRG products is illustrated on Fig. 3. It shows the systematic biases (left) and the standard deviations (right) versus the IGS solution in the tangential, cross-track and radial directions.

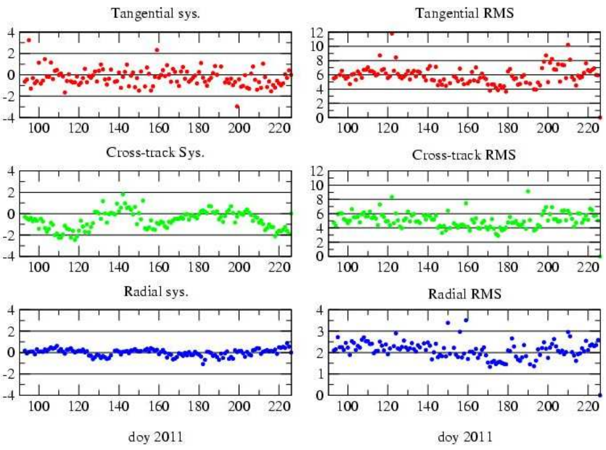

Figure 3. GRG GLONASS orbit evaluation (cm)

GPS and GLONASS GRG products were officially included in IGS final products on May 2010 and June 2011, respectively. More details about the GINS software and its processing concepts are available on the web site of CNES-CLS AC for IGS: www.igsac-cnes.cls.fr.

3. SIMULTANEOUS GALILEO AND GPS ORBIT DETERMINATION

Galileo will enhance the interest of GNSS for science, even during the constellation deployment, by increasing the amount of GNSS data currently limited to GPS and GLONASS satellites. However, any processing using the three constellations needs accurate Galileo orbits. The capability to process Galileo data with GINS has been implemented and tested on GIOVE-A and B satellites. The following results are based on a one month data set delivered by ESA to the geodetic community (December 2008; IGSMAIL-6191). They derive from a worldwide network of 13 hybrid GPS+Galileo receivers and an additional set of 140 GPS stations (Fig. 4). GIOVE-A and GIOVE-B data were processed simultaneously with the complete GPS constellation to estimate common parameters like receiver clocks and zenith tropospheric delays. These latter ones could not be estimated using only Galileo data because of the current limited number of satellites and tracking stations.

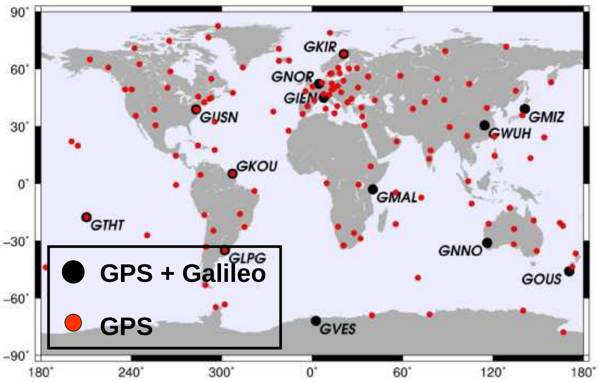

Figure 4. Galileo and GPS tracking network

Several implementations in GINS were needed:

- move to RINEX3 data format,
- manage different signal frequencies,
- update the Solar Radiation Pressure models,
- manage Galileo constellation.

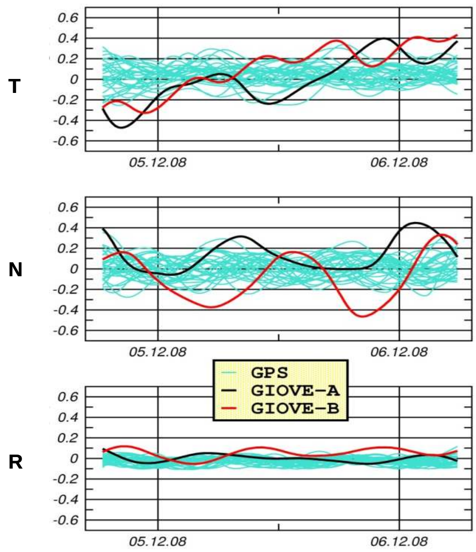

Figure 5. Comparisons between GINS and ESA/GMV orbits; network: 13 GPS/Galileo stations + 140 GPS stations(m)

We compared GPS, GIOVE-A and B satellites orbit solutions to ESA/GMV ones over the complete data set. On one hand, for both GIOVE satellites, the level of agreement is around 6cm RMS in the radial (R) direction and ~20-30cm on the tangential (T) and normal (N) directions. A plot of these comparisons is given in Fig. 5 for December 5, 2008. On the other hand, GPS orbit differences are at a sub-decimetre 3D-RMS level as expected.

In order to quantify the impact of the station network coverage we made a new orbit solution using only the 13 hybrid receivers GPS/Galileo network (Fig. 6). With such tracking network, the GPS orbit solutions are clearly degraded and become comparable to GIOVE ones.

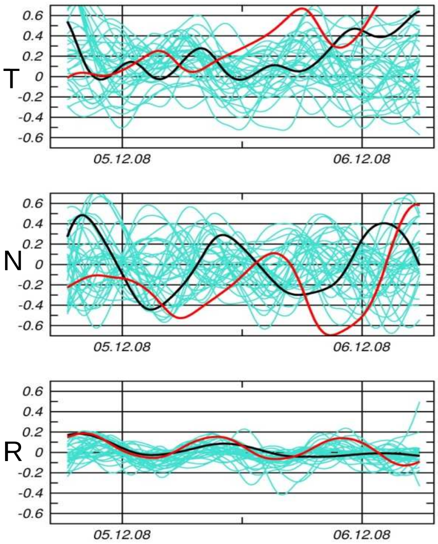

Figure 6. Comparison between GINS and ESA/GMV orbits; network: 13 GPS/Galileo stations (m)

We believe that the main limitation in GIOVE orbit determination is the lack of tracking stations. The highest level of accuracy will be reached for the Galileo constellation as soon as a dense network will be deployed.

4. HYBRID PPP USING GPS AND GLONASS DATA

Increasing the number of satellites in visibility may be helpful, especially for kinematic studies. Hybridizing GNSS systems like GPS and GLONASS today, and Galileo soon, is a factor of improvement because the number of observations is increased at each epoch. The GINS software offers the capability to combine GNSS data. Inter-system biases can be applied/estimated in order to get unique solutions to station related parameters like clock corrections or zenith tropospheric delays.

In the framework of GNSS campaigns in Antarctica, we computed several topographic profiles by tracking a mobile equipped with a GPS/GLONASS receiver. An additional interest of GLONASS at high latitudes is the 65° inclination of its constellation which enhances the geographic coverage as illustrated by Fig. 7.

Because no reference GNSS stations are available outside the coastal areas we could not make any double difference solution. We thus processed the data in a kinematic PPP mode (one independent position per epoch). We used GLONASS orbit and clock products from ESA/ESOC IGS AC [3].

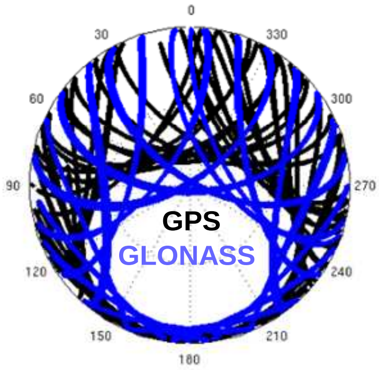

Figure 7. Typical GPS and GLONASS sky distribution in Antarctica

Fig. 8 (down) shows the number of GPS and GLONASS satellites in visibility. Fig. 8 (up) displays the East-West coordinates of the mobile in order to check the repeatability of the solutions (the blue plot has been shifted by 15cm for better reading). Here, the impact of combining two GNSS systems is obvious. We may think that future Galileo signals will improve significantly the accuracy of such GNSS positioning.

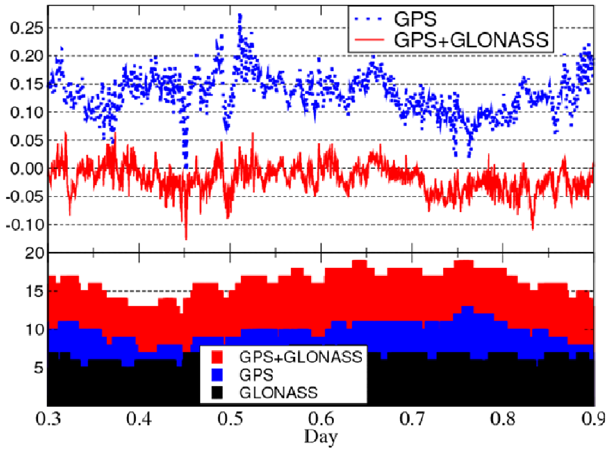

Figure 8. Kinematic PPP East-West component (m) using GPS data (blue) and GPS+GLONASS data (red)

5. KINEMATIC INTEGER PPP

Fixing ambiguities to integer values at the zero-difference level became recently a reality [4], [5], [6],

[7], [8]. The CNES-CLS IGS AC distributes GPS satellite clocks and uncalibrated phase delays (WSB; see section 2) that can be used to solve ambiguities in a PPP approach. This so called IPPP significantly improves single point positioning. As an example we computed OHI2 and OHI3 (fixed) IGS station coordinates every epoch (30s) in order to check the repeatability of the solution. The green plot in Fig. 9 displays the series of OHI3 East-West component derived from a classical double-difference approach (in which OHI2 coordinates were fixed). The red plot represents the difference of the two independent IPPP solutions (shifted by 5cm for better reading) obtained for OHI2 and OHI3. We mention that the distance between the two stations is ~3m and that 100% of phase ambiguities were fixed in both computations.

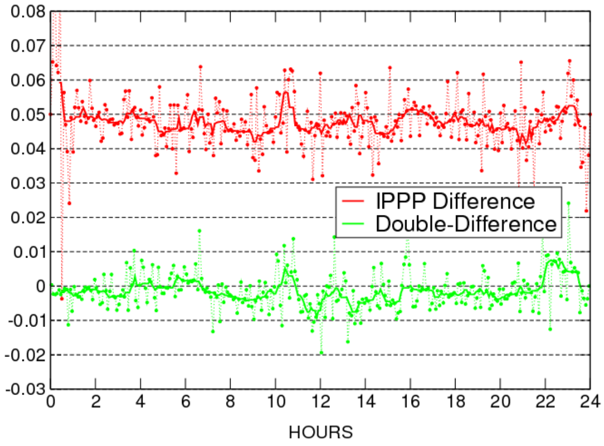

Figure 9. IPPP vs. DD series of East-West component (m) of OHI2 and OHI3 GPS stations

In both cases, RMS are around 6mm. This result illustrates the potentiality of IPPP to become an alternative approach to double-differences processing. It makes kinematic tracking of "isolated" mobiles like oceanic buoys or LEO satellites achievable.

6. CONCLUSIONS

CNES/GRGS have implemented GNSS data processing capability in its scientific GINS software. This paper gives 4 examples of applications:

- contribution of the CNES-CLS AC to GPS and GLONASS IGS products,
- simultaneous GIOVE and GPS orbit determination at the decimetre level,
- hybrid kinematic PPP using GPS and GLONASS data,
- comparisons of kinematic Integer PPP to double-differences solutions on a short baseline.

GINS derived GPS and GLONASS products are already at the precision level required by IGS. The increase of GNSS signals with Galileo announces future prospects in terms of accuracy. Orbits, satellite clocks, coordinate receivers, and every geodetic product/application will benefit from this, especially at high frequencies. GINS software is ready for this next generation.

7. ACKNOWLEDGEMENTS

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