Ocean loading effects in a high time resolution GPS analysis. Implications and artefacts with GINS GPS software.

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Introduction

The today's geodynamical and navigation applications of GNSS are being processed by a large variety of softwares where each one of them implements its own analysis strategy. The estimated unknown parameters of a LSQ (recursive or iterative) procedure can depend on theses strategies (reference frame definition, tropospheric parameterization, ambiguity resolution, receiver's antenna effect, stochastic parameterization etc.) which can induce artefacts in the estimated positions and velocities of geodetic points. The aim of this study is to analyse the geodynamical results coming from the methodology used by GINS GPS software. We are currently examining a DD network solution together with the Precise Point Positioning (PPP) strategy implemented in our software. To compare the strategies analysis, we use a set of 10 days from the 6 months GPS data acquired in the north-western France, Brittany in 2004 in order to study ocean loading. The ocean tides of this region can reach up to 10 m and produce loading effects up to 12 cm peak-to-peak on the vertical component and some cm-level displacements on the horizontal components of geodetic stations. In this specific case we need high time resolution GPS solutions to study short-periodic signals (diurnal, semi-diurnal, tier-diurnal, quart-diurnal, sixth-diurnal, and eighth-diurnal period signals) instead of classical 24h or hebdo-average solutions. Moreover, the equivalence in some cases between the loading effect and the processing artefacts sets up a sensitivity condition for the processing strategy (ambiguity resolution problem, constraints, tropospheric delay, ad-hoc models etc.). For example in GRGS we are currently producing our own GPS orbits and a comparison of the solutions with the ones from IGS orbits is examined. So it is essential to quantify the software's strategies impact on the GPS positioning. The different solutions are compared to the predicted positioning time series based on FES2004 (LEGOS) model in a local geodetic system NEU, which is considered as our reference in this study.

GPS Orbit estimation

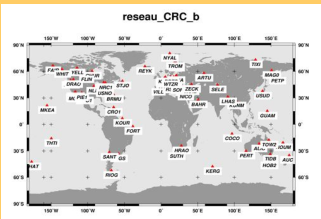


Fig.1: Network of 70 globally distributed stations

In GRGS we are currently producing our own GPS orbits from a network of 70 globally distributed permanent IGS stations (fig.1).

The estimation strategy consists of :

	GPS Constellation
Gravity field	Earth (12x12) GRIM5_c1 model + sun+moon+planets
Solar Radiation Pressure	Bar-Sever 1997 for blocks II -IIA + 1 scale factor/hr + Y-bias/day
Phase center corrections	Atx05, atx01 offsets + phase center variations PCVs (2 independent solutions)
Reference frame	ITRF2000 positions and velocities + EOPC04 + IERS predictions for Earth orientation
strategy	Undifferenced iono-free observations. Data sampling: 600 seconds

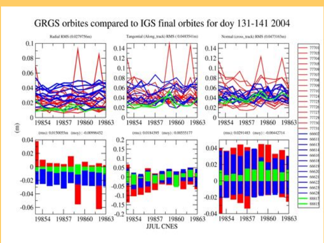


Fig.2: GRGS vs IGS orbits. In blue are the block IIR, in red are the block IIA, and in green the remaining 2 satellites of block II. We can clearly see that for the days 132-140 (up rows) we have a total rms agreement of 2,79cm in Radial, 4,83cm in Along track and 4,73 in Cross-track directions. Satellite prn24 is in eclipse (the 2 red peaks). No significant bias is observed (bottom rows).

In this study in order to evaluate the impact of the choice of the GPS orbits, we have used IGS final vs our GRGS orbits (absolute and relative offsets+PCVs) in the network solution. For the PPP solution we have chosen the COD final orbits and their 30s clocks.

From a first comparison of the GRGS orbits with the IGS final orbits we can comment that the mean 3D rms is of 7,32cm (fig.2).

We did the same comparison with the orbits provided by CODE analysis center and we have concluded that the overall agreement with the IGS final orbits in 3D rms is of 2,9cm (fig.3). For the PPP analysis we have used the CODE 30sec clocks and orbits in order to have the necessary consistency as demanded from the PPP absolute determination strategy.

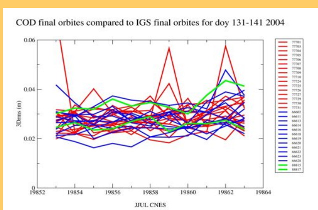


Fig.3: CODE vs IGS orbits. In blue are the block IIR, in red are the block IIA, and in green the remaining 2 satellites of block II. Here again we can see satellite 24 which enters in eclipse periods.

Network Solution

GINS/DYNAMO processing scheme

Initial iteration's scheme for determination of "healthy campaign-geodetic parameters".

- 1d-sessions, DD iono free observables
- IGS final precise orbits and EOP C04 fixed (contains 80% of GPS contribution, cf. IERS 2003 annual report)
- All stations are corrected for atmospheric loading using globally gridded ECMWF atmospheric pressure data of 6hrs (includes atmospheric tides).
- Solid earth tides (IERS 2003) and ocean tide loading (FES2004 T.Letelliier et al.) are corrected from all stations (campaign and IGS)
- Satellite and receiver relative phase center offsets (atx01 conventions) together with phase center variation maps.
- Campaign stations adjusted, together with IGS stations constrained at 1mm. Ambiguities are resolved as real parameters. Tropospheric parameters are adjusted for every hour from a Saastamonien a-priori model.
- Initialization of the station file with the "healthy" parameters

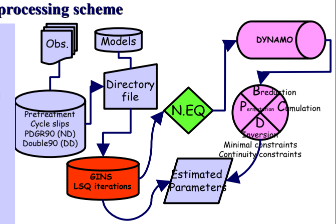


Fig. 4 GINS GPS software analysis scheme

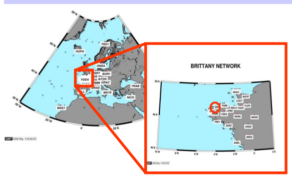


Fig. 5 The regional GPS network and the campaign stations

Final iteration's scheme, high time resolution analysis

- 1d-sessions, geodetic parameters and quasi-observables (partials) created for every 1-hr at last iteration free of constraints
- 12 campaign stations, 5 French permanent stations, 9 IGS stations
- IGS final precise orbits and EOP fixed
- ZTD estimated every 1hr., no horizontal gradients, cut off 10°
- Correction for solid earth tides and atmospheric loading, no ocean tide loading correction to campaign and RGP (French) stations, satellite and receiver antenna relative IGS offsets and PCVs.
- A priori coordinates for IGS stations are corrected of the OTL effects given by FES2004 model (T. Letellier et al.) on the 3 components
- Ambiguities are fixed (in general over 90% in all cases) and eliminated in the iteration scheme.

Reference System realization , Final solution DYNAMO
Solution tight to the «ITRF00 corrected for FES2004 OTL model »

- ***Constraint solution :*** 1mm constraints on IGS position and continuity constraints of 1cm to BRITANY/RGP stations in the NEU local geodetic frame

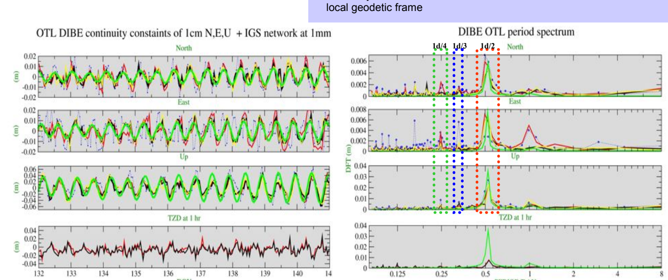


Fig. 6 **On the left:** High time series for the « Le Diben » station in North, East and Up components. TZD parameters are estimated every hour. In blue is a solution with no corrections of the PCVs, with relative phase center offsets and no ambiguity fixing. **In red** is the solution with PCVs and phase center offsets according to the atx01 conventions (relatives) and no ambiguity fixing. **In black** is the solution with PCVs and phase center offsets according to the atx01 conventions and with ambiguity fixing. **In yellow** is the solution with PCVs and phase center offsets according to the atx05 conventions, with ambiguity fixing and our final GRGS orbits of the atx05 solution **. The most consistent time series with the model are the black (IGS orbits) and yellow solutions (GRGS orbits). In green** are the displacements from the Green's convolutions with the FES2004 model.

On the right : Period spectrum of the N, E, Up and TZD parameters. Obviously the PCVs are acting positive to the high time position determination and ambiguity fixing is improving significantly the noise in the East component as previously mentioned by (King et al, 2003) and (Blewitt, 1989). Nevertheless, our time series shows for both reference solutions (black with IGS orbits and yellow with GRGS orbits) displacements in the frequency domain of the non linear tide waves of M3, M4 and even M6. After discussion with the team of F. Lyard of LEGOS laboratory we have concluded than this signals are not fictitious but real ones (T.Letellier, 2004).

Correlation with FES 2004 modeled displacements and sensitivity analysis

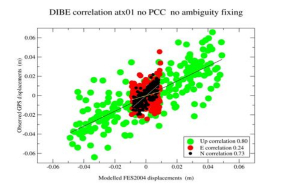
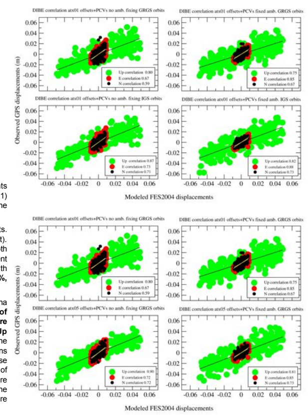


Fig. 7 **Up left :** correlation coefficients wrt the modeled FES2004 displacements and the observed GPS solutions with no PCVs, relative phase center offsets (atx01) and no ambiguity fixing. The correlation for the **Up=80% , E=24% and N=73%** The influence of non ambiguity fixing is obvious in the east component.

Up right : Comparisons between solutions with fixed IGS vs GRGS final orbits. Atx01 antenna offsets+PCVs and with or without ambiguities fixed (left vs right). Notice the improvement for the East component when fixing ambiguities. Both solutions (IGS vs GRGS) give according to the regression analysis consistent results. The WRMS for the **Up=19mm, E=6mm, N=6mm** in the best case with GRGS orbits. Correlations (right column, ambiguities fixed) are **Up=82%, E=88%, N=73%** for IGS orbits and **Up=75%, E=85%, N=67%** for GRGS orbits.

Bottom right : Comparisons between atx01 (Up row) or atx05 (down row) antenna offsets and PCVs. All orbits are GRGS final orbits. **Notice that the application of the absolute conventions for antenna offsets and PCVs does give more consistent results (better correlations) and better repeatabilities for the Up and North components**. Although when fixing ambiguities, the repeatability for the east component remains unchanged wrt the antenna model. In general correlations for atx01 case and fixed ambiguities are **Up=75%, E=85%, N=67%.** For atx05 case correlations with fixed ambiguities are **Up=81%, E=85%, N=73%.** In the case of absolute antenna offsets and PCVs there might be a mitigation of bad troposphere modeling specially when fixing ambiguities. More investigation of the role of the troposphere is also needed in the case where absolute PCVs and offsets are applied. The WRMS for the **Up=20mm, E=7mm, N=7mm** in the best case.



PPP analysis strategie

- 1d-sessions, geodetic parameters and quasi-observables (partials) created for every 1-hr
- 1 campaign station treated "Le Diben"
- CODE final precise orbits, CODE 30sec GPS clocks and EOP fixed.
- ZTD estimated every 1hr no horizontal gradients, cut off 10°
- Correction for solid earth tides and atmospheric loading, no ocean tide loading correction to campaign station, satellite and receiver antenna relative atx01 corrections + PCVs
- Ambiguities are estimated
- Station clock's are estimated
- Elimination of outliers at the 7th iteration with a 4sigma criterion in phase and code measurements.

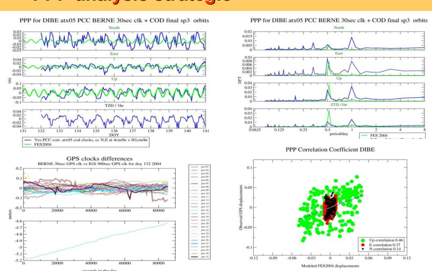


Fig. 8 Up left: High time series for N,E,Up and TZDs params. Repeatabilities are poor.

Up right : Period spectrum for all 3 components + TZDs. Part of the signal is mitigated to the TZDs estimates. Noise is observed to the lower period (high frequency) spectrum displacements. Is it actually a remaining physical signal ?

Bottom left: Comparisons between CODE 30sec clocks and IGS 15 min clocks. Consistency remains well under 8cm.

Bottom right: correlation of the modeled FES2004 displacements and the observed GPS solutions. Very poor correlation to all components Up=46%, E=37%, N=14%.

Aknowledgements

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Références

Biancale, R. and Bode A., Mean Annual and Seasonal Atmospheric Tide Models Based on 3-hourly ECMWF Surface Pressure Data, GFZ, Scientific Technical Report STR06/01

King, M., Coleman, R., Nguyen, L. N., Spurious periodic horizontal signals in sub-daily GPS position estimates, *Journal of Geodesy*, (2003) 77 : 15 – 21

Blewitt, G., Carrier Ambiguity Resolution for the Global Positioning System Applied to Geodetic Baselines up to 2000 km, *JGR,* Vol. 94, No. B8, p. 10,187 – 10,203

T. Letellier, Etude des ondes de marée sur les plateux continentaux, Phd thesis report (in French), (2004) Université Toulouse III