Precise Point Positioning with ATOMIUM using IGS Orbit and Clock Products : First Results

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***Abstract*— In this paper, we investigate the quality of the station positions determined by Precise Point Positioning using ATOMIUM. For that purpose the IGS orbits and clock files are considered as a priori information while ATOMIUM estimates daily station positions, hourly tropospheric zenith path delays and epoch-wise station clock synchronization errors with respect to the IGS time.**

In addition to its very fast operation (a daily run takes about 5 seconds by station), the mean weekly position repeatability obtained with ATOMIUM is at the level of 3.9 mm for the north, 2.4 mm for the east and 6.8 mm for the up component. If in addition, a Helmert transformation is performed to more reliably express the solution in the IGS05, then the mean weekly station position repeatabilities reach 3.1 mm for the north, 1.9 mm for the east and 5.7 mm for the up component, i.e. similar to what is presently obtained with the Bernese.

I. Introduction

The software ATOMIUM was originally developed by the ROB (Royal Observatory of Belgium) for GNSS-based time transfer. ATOMIUM inputs GNSS code and carrier phase measurements and uses a least-square analysis to determine a daily station position and epoch-wise station clock errors, using either a zero-difference approach (Precise Point Positioning, PPP) or a single difference approach (also called Common-View).

This paper presents an evaluation of the performances of ATOMIUM to carry out precise positioning using the zero-difference approach. Section II outlines how ATOMIUM works and section III explains the data analysis performed for this study. The position results obtained with ATOMIUM and their comparison with the Bernese solutions are presented in section IV. This section also shows the improvements that a Helmert transformation between the daily PPP positions obtained by ATOMIUM and the IGS05 can bring to the weekly repeatabilities.

II. Description of Atomium

The PPP approach of ATOMIUM is based on a least-square adjustment of daily batches of GPS ionosphere-free code and carrier-phase measurements from one station. The observations are first corrected for the effects of solid Earth tides and ocean loading following the IERS conventions [1]. Satellite positions are introduced a priori and are obtained from the IGS (International GNSS Service) orbits using a Neville interpolation (on 12 points at a 15-min sampling rate). The satellite clock corrections, also introduced a priori, are taken from IGS clock products. Both satellite and receiver antenna positions are corrected for respectively nadir-dependent and elevation-dependent phase center variations with absolute corrections provided by the IGS (file igs05.atx) [4]. The carrier-phase measurements are also corrected for phase windup [5] taking into account satellite attitude and eclipse events. The hydrostatic part of the tropospheric delay is introduced a priori using the dry Saastamoinan model [2] and the dry Niell mapping function (NMF) [3]. The wet part of the tropospheric zenith delay is estimated with a 2-hour sampling rate in the least-square adjustment. In addition, a daily station position is estimated as well as the station clock synchronization error with the respect to the IGS time scale for each observation epoch (5 minutes in the present study). Typically a daily run takes about 5 seconds by station.

III. Data Analysis

The data analysis consists of a two-step approach. In a first step, the positions of 98 globally-distributed IGS05 [7] and 264 EPN [6] stations (see Figure 1) were computed by PPP with ATOMIUM for the period 2007- early 2009 using final IGS orbits and clocks, and an elevation cutoff of 10 degrees.
In a second step, the obtained PPP positions were transformed in the IGS05 reference frame using a Helmert transformation. Indeed, the PPP positions obtained with ATOMIUM are expressed in the reference frame of the IGS final orbits, which is minimally constrained (rotations only) with respect to IGS05 position/velocity solutions of the IGS reference frame stations. Consequently, the IGS final orbits/clocks refer to an instantaneous geocentric frame of which the origin does not coincide with the origin of the ITRF2005 (or IGS05), and of which the scale is also different. To remove the effect of this instantaneous frame, the PPP positions were expressed in the IGS05 frame using a Helmert transformation on the 98 IGS05 reference stations.

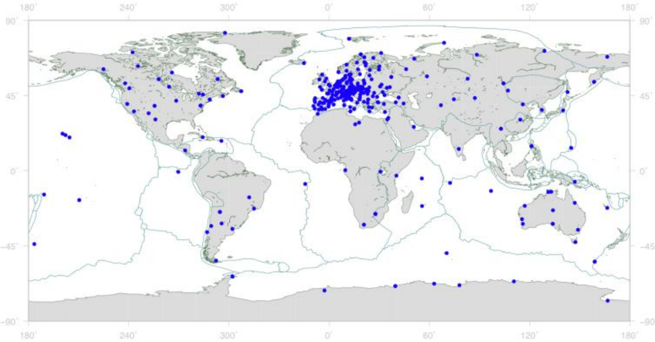

Figure 1. EPN and IGS05 stations used in this study.

Additionally, a set of ten stations was chosen among the IGS stations analyzed with ATOMIUM, and the Bernese software v5.0 [8] was used to produce for these stations parallel PPP solutions based on similar processing options (NMF, 10° elevation cutoff and IGS final orbits and clocks). The ATOMIUM and Bernese solutions obtained for these stations will be compared in the next section.

IV. POSITION RESULTS

Results of the PPP analysis

1. Comparison with EPN double difference network results

The top plot of Figure 2 shows the time series of the differences between the daily coordinates obtained with ATOMIUM and the IGS05 coordinates for the station GLSV (Kiev, Ukraine). The bottom part of Figure 2 shows for comparison the residual position time series obtained by stacking the EPN combined solution (http://www.epncb.oma.be/_dataproducts/products/timeseriesanalysis/residual.php) which is originally based on a carrier-phase double difference network adjustment. In the PPP results, a change in the noise level before and after an antenna change (red line) at GLSV can be seen. This effect is clearly not visible from the EPN combined solution. A possible source of this difference could be the noise and multipath of the GLSV code data which are used in the PPP approach but not in the double difference EPN approach. Also the coordinate jump associated with the antenna change is different. Both effects will have to be studied in more details in the future. Figure 2 also shows an annual signal in the East component of the Atomium results which is not present in the EPN solution. As we will show later, this annual signal is caused by the reference frame.

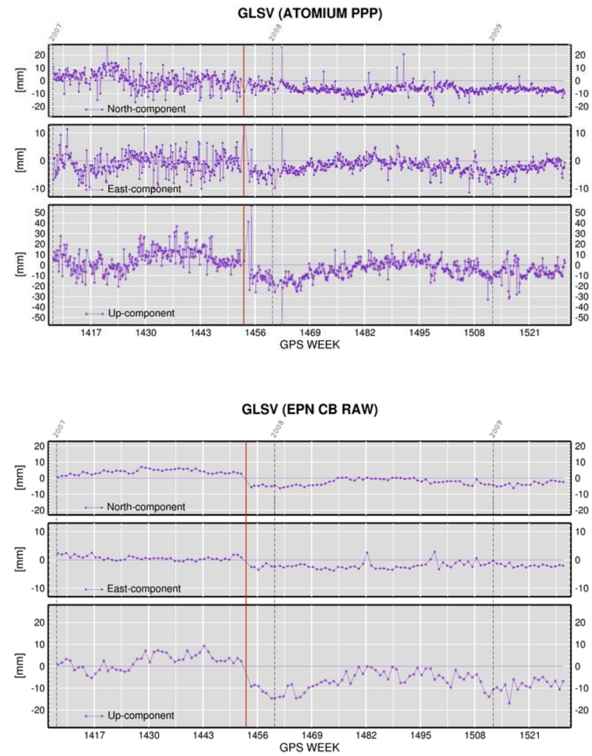

Figure 2. Time series for GLSV, top: differences between the daily estimated coordinates with ATOMIUM and the IGS05 coordinates (site velocity was removed) and bottom: residual position time series from the EPN combined solution.

2. Comparison with Bernese PPP results

To assess the quality of the ATOMIUM results, we also compared them with Bernese PPP on a set of 10 stations. In both cases, no Helmert transformation was performed to express the solutions in the IGS05. The time series of the differences between the daily coordinates computed using PPP and the IGS05 coordinates for the station ONSA (Onsala, Sweden) are shown in the top Figures 3 (obtained with ATOMIUM) and 4 (obtained with Bernese). They show similar variations in the three components, indicating that these variations with the respect to IGS05 are due to the PPP approach. In order to test the differences between the PPP results from ATOMIUM and from Bernese, we also plotted in Figure 5 the differences between the daily coordinates estimated with both software tools. These differences do not contain the large variations observed in Figures 3 and 4, which confirms that these latter find their origin in the PPP approach. Figures 3 and 4 (bottom) show, for the 10 stations selected for this study, the mean weekly repeatability over the two-year period investigated here, obtained with ATOMIUM and Bernese. Using ATOMIUM, this repeatability is about 3.9 mm for the north component (3.6 mm for the Bernese), 2.4 mm for the east component (2.2 mm for the Bernese) and 6.8 mm for the up component (6.3 for the Bernese).

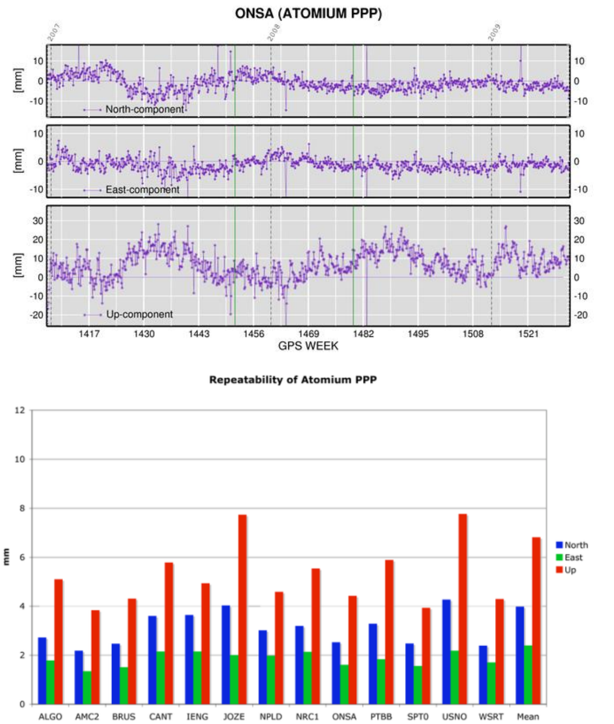

Figure 3. Top: differences between the daily coordinates estimated with ATOMIUM and the IGS05 coordinates (site velocity was removed) for the station ONSA . Bottom: Mean weekly position repeatability of ten IGS stations, obtained using PPP with ATOMIUM over the two year period investigated.

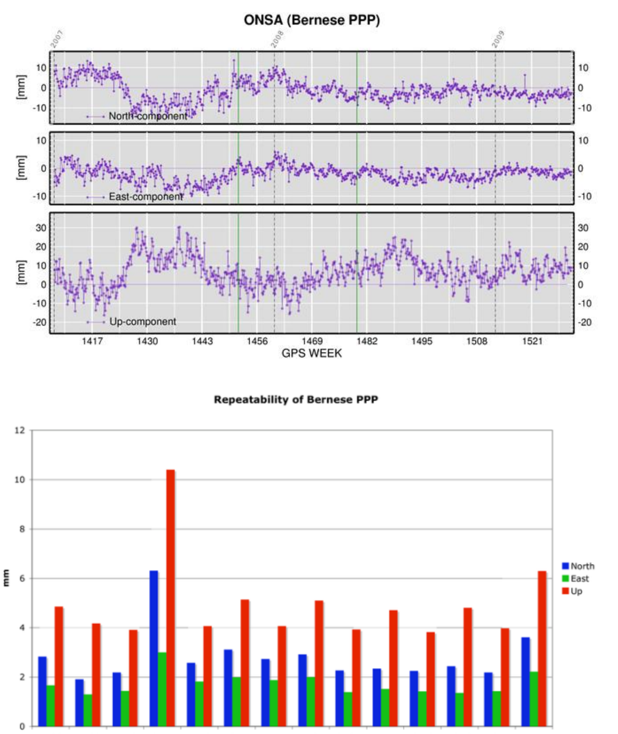

Figure 4. Top: differences between the daily coordinates estimated with Bernese using PPP and the IGS05 coordinates (site velocity was removed) for the station ONSA. Bottom: Mean weekly position repeatability of ten IGS stations obtained using PPP with Bernese over the two year period investigated.

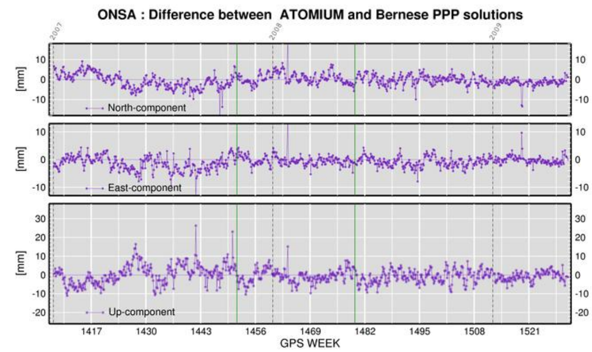

Figure 5. Differences between the daily coordinates of ONSA estimated in PPP with ATOMIUM and Bernese .

Results of the Helmert Transformation

Seven Helmert transformation parameters have been first estimated, each day, between the daily instantaneous positions computed by ATOMIUM and the IGS05; these are given in Figure 6. Only stations with Helmert residuals smaller than 1.5 cm in the horizontal and 3 cm in the vertical component have been included in the computation of the Helmert parameters.

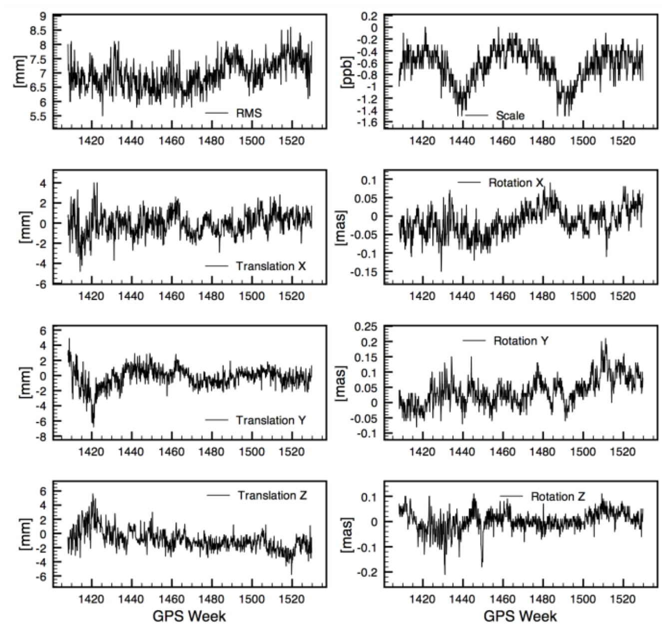

Figure 6. Helmert transformation parameters between daily PPP positions and IGS05. The upper left figure shows the RMS of the residuals of the transformation. Stations with residuals exceeding 1.5 cm in the horizontal and 3 cm in the vertical component have been excluded for the computation of the Helmert parameters.

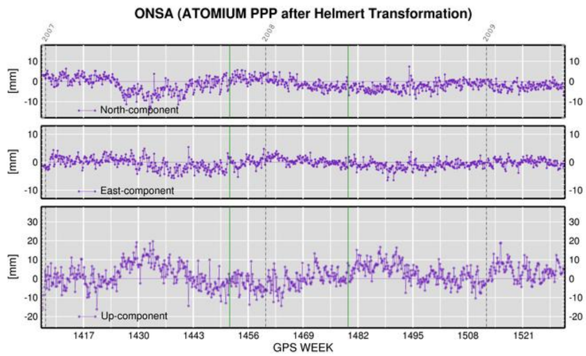

Figure 7. Differences between ATOMIUM PPP daily coordinates and IGS05 coordinates of ONSA after a Helmert transformation.

The comparison of our Helmert transformation parameters with those obtained by the IGS Analysis Center Coordinator (http://acc.igs.org) between the IGS PPP daily positions and IGS05) shows a good agreement for the rotations, the translations and scale.

In order to remove the orbit-dependant effects and reliably express our daily PPP solutions in IGS05, each day, the estimated transformation parameters have been applied to the PPP solution. Once the daily solutions are expressed in IGS05 using the Helmert transformation, the large variations with respect to IGS05 are reduced or removed (Figure 7) and the mean weekly position repeatability is improved for the three components (Figure 8), by about 18% for the horizontal components and about 15% for the vertical component.

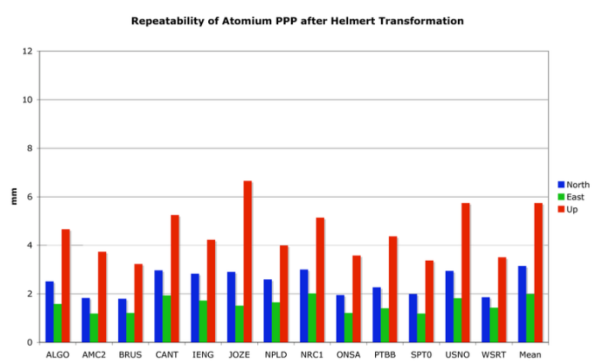

Figure 8. Mean weekly repeatability computed with ATOMIUM for the same ten stations as before, after an Helmert transformation.

V. Conclusions and Perspectives

ATOMIUM is already a powerful tool to perform time transfer. In this study, we focused on the positions outcome of ATOMIUM using a PPP analysis. For that purpose, we computed with ATOMIUM the daily positions of more than 350 stations included in the IGS05 or in the EPN, over a period exceeding two years. We showed that the mean weekly repeatability obtained with ATOMIUM for a set of ten stations is at the level of 3.9 mm for the north, 2.4 mm for the east and 6.8 mm for the up component.

Each day, a Helmert transformation (7 parameters) allows aligning the daily ATOMIUM solution to the IGS05. After these Helmert transformations, the resulting mean weekly repeatabilities obtained for the same ten stations reach 3.1 mm for the north, 1.9 mm for the east and 5.7 mm for the up component. These results are therefore very promising for the use of ATOMIUM in an operational mode for station monitoring.

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