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IGS contribution to the ITRF

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Abstract We examine the contribution of the International GNSS Service (IGS) to the International Terrestrial Reference Frame (ITRF) by evaluating the quality of the incorporated solutions as well as their major role in the ITRF formation. Starting with the ITRF2005, the ITRF is constructed with input data in the form of time series of station positions (weekly for satellite techniques and daily for VLBI) and daily Earth Orientation Parameters. Analysis of time series of station positions is a fundamental first step in the ITRF elaboration, allowing to assess not only the stations behavior, but also the frame parameters and in particular the physical ones, namely the origin and the scale. As it will be seen, given the poor number and distribution of SLR and VLBI co-location sites, the IGS GPS network plays a major role by connecting these two techniques together, given their relevance for the definition of the origin and the scale of the ITRF. Time series analysis of the IGS weekly combined and other individual Analysis Center solutions indicates an internal precision (or repeatability) <2 mm in the horizontal component and <5 mm in the vertical component. Analysis of three AC weekly solutions shows generally poor agreement in origin and scale, with some indication of better agreement when the IGS started to use the absolute model of antenna phase center variations after the GPS week 1400 (November 2006).

Keywords Reference systems · Reference frames · ITRF · GPS · Earth rotation · IGS

1 Introduction

Station positions derived from observations of the Global Positioning System (GPS) were first included in the formation of the International Terrestrial Reference Frame (ITRF) in 1992, starting with the ITRF91 (Boucher et al. 1992). The International GNSS Service (IGS), formerly the International GPS Service, is a voluntary federation of more than 200 worldwide agencies aiming at providing the highest quality of GPS and GLONASS products, mainly precise orbits, clock corrections, station positions and Earth rotation parameters. In parallel, all the IGS products are expressed directly or indirectly in the ITRF frames. At the inception of its activities, the IGS used directly the ITRF frames to be the underlying frame of its products (Kouba 1995, 1998, 2003). Following the methodology of Kouba et al. (1998), the IGS started in 2000 to form its own, internally more consistent GPS-only frame, but still inheriting the ITRF datum in terms of origin, scale and orientation and their rates of change (Ferland 2004). A more detailed history of IGS reference frame realizations can be found in Ray (2004); Ray et al. (2004). Starting with GPS week 1400, the IGS has switched from relative to absolute model corrections to account for antenna phase center variations (PCV). In the same time, the IGS has adopted the ITRF2005 (Altamimi et al. 2007) to form its specific frame called IGS05, composed of about 100 sites whose ITRF2005 coordinates were corrected to account for relative to absolute PCV differences. In order to preserve the ITRF2005 datum (origin, scale and orientation) the IGS05 was aligned to the ITRF2005 using a 14-parameter similarity transformation (Ferland 2006). In reality, among the 14 parameters, only the scale factor was significant, representing the mean height difference of IGS05 station positions estimated with relative and absolute PCVs.

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Since almost 10 years, initiated first by the IGS, analysis centers of three other IERS techniques (VLBI, SLR, DORIS) started to make available time series of station positions and Earth Orientation Parameters (EOPs) provided in SINEX format. The power of time series of station positions, allowing to control not only the station behavior and in particular to monitor non-linear motion, but also the frame physical parameters (origin and scale) led the ITRF Product Center to consider them as input for the ITRF generation, starting with the ITRF2005. In addition to station positions and velocities, ITRF2005 integrates also consistent daily EOPs. The latter was already used by the IERS EOP Product center in order to improve the consistency of the IERS operational series of EOPs with the ITRF (Altamimi et al. 2008). The ITRF input time series solutions are provided on a weekly basis by the IAG International Services of satellite techniques: the IGS, (Dow et al. 2005), the International Laser Ranging Service (ILRS), (Pearlman et al. 2002) and the International DORIS Service (IDS), (Tavernier et al. 2005), and in a daily (VLBI session-wise) basis by the International VLBI Service (IVS), (Schlueter et al. 2002). Each per-technique time series is already a combination of the individual Analysis Center solutions of that technique.

2 Current procedure for ITRF construction

In order to give the reader the necessary information regarding the current procedure adopted for the ITRF formation, we recall here that this procedure involves two steps: (1) stacking the individual time series to estimate a long-term solution per technique comprising station positions at a reference epoch and velocities and daily EOPs; and (2) combining the resulting long-term solutions of the four techniques together with the local ties at co-location sites. In addition, the combination model incorporates station positions and EOPs using the following two sets of equations, involving the 14-parameter similarity transformation:

$$\left\{\begin{array}{l} X_s^i = X_c^i + (t_s^i - t_0)\dot{X}_c^i \\ \qquad + T_k + D_k X_c^i + R_k X_c^i \\ \qquad + (t_s^i - t_k)\left[\dot{T}_k + \dot{D}_k X_c^i + \dot{R}_k X_c^i\right] \\ \\ \dot{X}_s^i = \dot{X}_c^i + \dot{T}_k + \dot{D}_k X_c^i + \dot{R}_k X_c^i \end{array}\right. \tag{1}$$

where for each point i, X_s^i (at epoch t_s^i) and $\dot{X}_s^i$ are positions and velocities of technique solution s and X_c^i (at epoch t_0) and $\dot{X}_c^i$ are those of the combined solution c. For each individual frame k, as implicitly defined by solution s, D_k is the scale factor, T_k the translation vector and R_k rotation matrix. The dotted parameters designate their derivatives with respect to time. The translation vector T_k is composed of three origin components, namely $T1$, $T2$, $T3$, and the rotation matrix of three small rotation parameters: $R1$, $R2$, $R3$, according to the three axes, respectively X, Y, Z. t_k is a conventionally selected epoch of the seven transformation parameters, which is, in case of time series stacking, the epoch of the week.

In addition to Eq. 1 involving station positions (and velocities), the EOPs are added by the following equations, making use of pole coordinates x_s^p, y_s^p and universal time $\mathrm{UT_s}$ as well as their daily rates $\dot{x}_s^p$, $\dot{y}_s^p$ and $\mathrm{LOD_s}$:

$$\left\{\begin{array}{ll} x_s^p & = x_c^p + R2_k \\ y_s^p & = y_c^p + R1_k \\ \mathrm{UT_s} & = \mathrm{UT_c} - \frac{1}{f} R3_k \\ \dot{x}_s^p & = \dot{x}_c^p + \dot{R}2_k \\ \dot{y}_s^p & = \dot{y}_c^p + \dot{R}1_k \\ \mathrm{LOD_s} & = \mathrm{LOD_c} + \frac{\Lambda_0}{f} \dot{R}3_k \end{array}\right. \tag{2}$$

where $f = 1.002737909350795$ is the conversion factor from UT into sidereal time. The last line of Eq. 2 is derived from the relation between LOD and UT, that is $\mathrm{LOD} = \int_t^{t+\Lambda_0} \mathrm{dUT}$. Given the assumption that $\frac{\mathrm{dUT}}{\mathrm{d}t}$ is constant in the interval $[t, t+\Lambda_0]$, then $\mathrm{LOD} = -\Lambda_0 \frac{\mathrm{dUT}}{\mathrm{d}t}$. Λ_0 is homogenous to time difference, so that $\Lambda_0 = 1$ day in time unit.

Note that the link between EOP and the Terrestrial Reference Frame (TRF) is ensured upon the three rotation angles $R1$, $R2$, $R3$, and their time derivatives $\dot{R}1$, $\dot{R}2$, $\dot{R}3$. Therefore, the EOP values follow faithfully the defined combined frame.

The combination consists of estimating:

- Positions X_c^i at a given epoch t_0 and velocities $\dot{X}_c^i$ in the combined frame c.
- Transformation parameters (T_k, D_k and R_k) at an epoch t_k and their rates ($\dot{T}_k$, $\dot{D}_k$, $\dot{R}_k$), from the combined frame to each individual frame k.
- Daily EOPs.

The normal equation system constructed upon the above combination model is singular and has a rank deficiency of 14 corresponding to the number of the parameters that are necessary to define the combined frame in origin, scale and orientation. There are several ways to add additional constraints to define the combined frame, two of which are based on minimum conditions involving the 14 degrees of freedom (and not more): the classical method of minimum constraints (Sillard and Boucher 2001; Altamimi et al. 2002a, 2004) and a method imposing internal conditions in case of time series stacking (Altamimi et al. 2007).

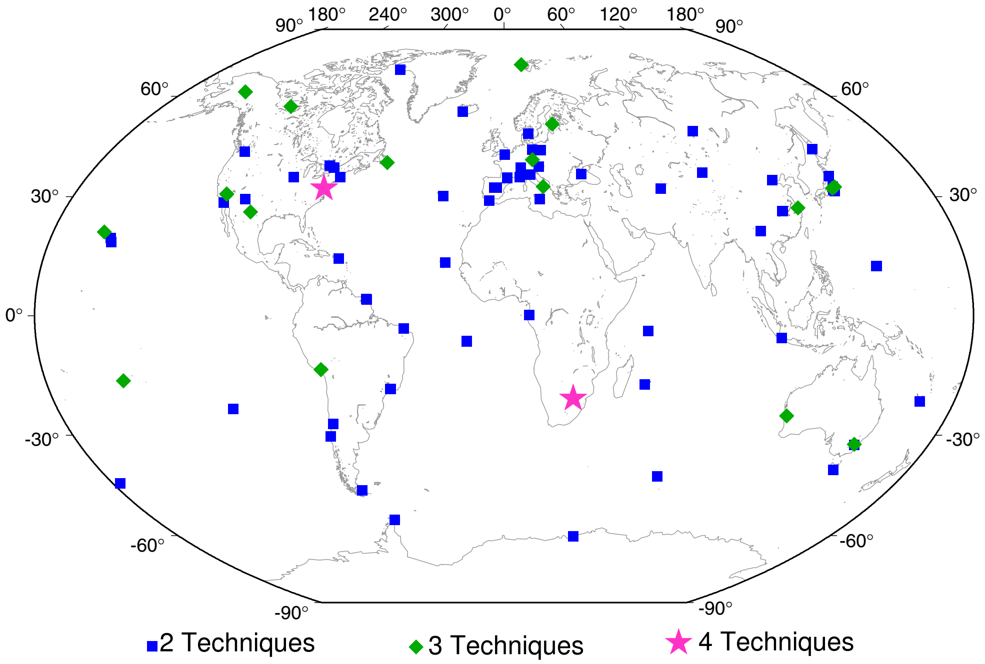

Fig. 1 Currently available co-location sites (2008)

3 IGS contribution to the ITRF

3.1 GPS and ITRF co-locations

The key-element of a multi-technique combined frame as the ITRF is the availability of a sufficient number and worldwide distributed co-location sites. A co-location site is defined by the fact that two or more space geodesy instruments are occupying simultaneously or subsequently very close locations which are very precisely surveyed in three dimensions, using geodetic classical surveys or the GPS technique. Classical surveys are usually direction angles, distances, and spirit levelling measurements between instrument reference points or geodetic markers. Adjustments by least squares of local surveys are generally performed by national geodetic agencies operating space geodesy instruments yielding differential coordinates (local ties) connecting the co-located instruments reference points.

Figure 1 illustrates the status of co-location sites where stations from the four techniques (VLBI, SLR, GPS, DORIS) are currently operating. All in all there are 58 sites with two techniques, 16 sites with three techniques, and only two sites with the four techniques. The Greenbelt (MD, USA) four-technique site includes an old VLBI mobile antenna of a very low performance. Among the 58 two-technique sites, 38 are GPS-DORIS co-locations. We note also that about 15% of the available local tie vectors have discrepancies larger than 1 cm with space geodesy estimates. There are only eight sites where VLBI and SLR are co-located, a very poor number to ensure optimal connection between these two techniques. In ITRF combinations, the GPS now plays a major role connecting both techniques, given the fact that all SLR and VLBI sites are co-located with permanent GPS/IGS stations. The drawback of this situation is that if there is any GPS related bias, this would contaminate the ITRF defining parameters, mainly the origin and the scale, being determined by SLR and VLBI. One of the major GPS weaknesses is the existence of position discontinuities due to equipment changes that affect more than 50% of the IGS network. In addition, there are a certain number of GPS stations with uncalibrated radomes. Given these preponderant weaknesses and the currently available local ties and their uncertainties, we estimate the quality of the local ties to be at the level of 4 mm, as the weighted mean of the tie residuals resulting from the current ITRF combinations.

3.2 Strengths and weaknesses of GPS

Each one of the four techniques used in the ITRF combination has its own strengths and weaknesses. Therefore the ITRF combination benefits from the strengths of all the four techniques, while mitigating, and underlining, their weaknesses. Starting with the strengths of GPS for the ITRF, we can mention the following main points:

– the spatial density and distribution of the IGS/GPS sites result in a very good coverage and sampling of the main tectonic plates. This is an important aspect because it allows a precise determination of the ITRF orientation time evolution. In effect, the ITRF should satisfy the

no-net-rotation (NNR) condition which is directly applied using the plates as a discretization of the Earth surface;
- GPS is providing the most precise polar motion, being based on continuous observation of a dense network;
- using IGS products (orbits and clocks), GPS allows real time or near real time access to the ITRF;
- as described in the previous section, GPS is strengthening the link between VLBI and SLR networks in the ITRF combinations.

On the other hand, considering the vital role and the requirement for a stable and reliable reference frame and its maintenance over time, we can mention the following weaknesses of the GPS technique and the IGS network as seen by the ITRF combination:

- imprecise origin and geocenter estimates mainly due to orbit mismodeling errors;
- imprecise TRF scale determination due to PCV of the ground and satellite antennas;
- 50% of the IGS sites have discontinuities in the position time series due to equipment changes (antenna, receiver, radome);
- many of the IGS reference frame stations need to improve their quality and performance, continuous operation and stability. They should follow strict standards of installation, operation and monumentation as defined in the IGS site guidelines (IGS 2007) in order to secure the minimum requirements on the stability of the IGS reference frame. A set of proposed specifications for reference frame stations has been published by Ray (2004).

4 Analysis of GPS time series

The CATREF combination model described above is well adapted for stacking and analysis of time series of station positions and EOPs (Altamimi et al. 2007). Time series analysis allows to evaluate not only the station motions and their variability, but also the behavior over time of the frame parameters and in particular the physical ones, namely the origin and the scale. In order to evaluate the quality and temporal behavior of GPS weekly solutions of station positions and EOPs, we present here the results of the analysis of the IGS official time series covering the period 1996.0–2008.2, the MIT (Massachusetts Institute of Technology, USA), the NGS (National Geodetic Survey, USA) and the GFZ (GeoForschungsZentrum Potsdam, Germany) weekly solutions over the period 2003.1 to 2008.4.

4.1 Repeatability of GPS station positions

The quality of station position time series is often assessed by estimating Helmert parameters of their corresponding frames with respect to an external secular reference frame and by studying their repeatability. The analysis of the estimated station horizontal and vertical velocity field as well as the large scale non linear displacement field (Blewitt et al. 2001; Wu et al. 2006) may complete the study by assessing the physical meaning of the data set. We use here the Weighted Root Mean Square (WRMS) described in Altamimi et al. (2002b), Eq. A19, as a statistical estimator to qualify the precision or repeatability of the GPS time series of station positions. Figure 2 displays the WRMS of the weekly analyzed time series of GFZ, MIT, NGS and IGS combined. Note that the IGS combined weekly solutions are the results of the combination of weekly solutions of eight analysis centers contributing to the IGS combined products (Ferland and Piraszewski 2008). It is expected that the quality of the combined IGS solutions is superior to any individual AC solution. From Fig. 2 we can easily see that the internal IGS combined precision (repeatability) now reaches the level of 1.8–2.0 mm in the horizontal component and 5 mm in the vertical component. From that Figure we can also see an indication of improvement of the three AC solutions, starting with 5 and 7 in the early dates, to reach now 2 and 5 mm in horizontal and vertical components, respectively. We also note that the scattering is significantly reduced, mainly for GFZ and NGS, a few weeks after the famous week 1400 where the IGS started to use the absolute PCV corrections instead of the relative model.

Among the four techniques that actually supply data for the ITRF generation, the GPS WRMS time series exhibits the less scattered statistics with the lowest values due to the internal precision and the denser tracking network of the GPS technique . We expect these statistics to reflect the technique performance but its interpretation is delicate since non modelled station motion contributes to its variation. As linear variations are accounted for in the stacking model of the CATREF software, from which these statistics are derived, only non linear station position variations, mostly due to the loading effects and systematic technique errors, contribute to these values. Even if the measurement technique were perfect, the WRMS time series would not be zero due to loading effects embedded in the GPS measurements. The question is to know how much that physical signal contributes to the WRMS values to investigate what GPS precision actually is. In order to examine the current accuracy of the IGS combined solution, we evaluated the station position repeatability due to loading effects by simulating nonlinear variations of station positions. For this purpose, we investigate the vertical and horizontal WRMS of the IGS weekly solutions that have been submitted for the ITRF2005 generation, spanning the period 1996.0 to 2006.0 as a reference. These WRMS values are plotted in blue in Fig. 3. The median values reach 2.1 and 5.6 mm on the horizontal and vertical components, respectively.

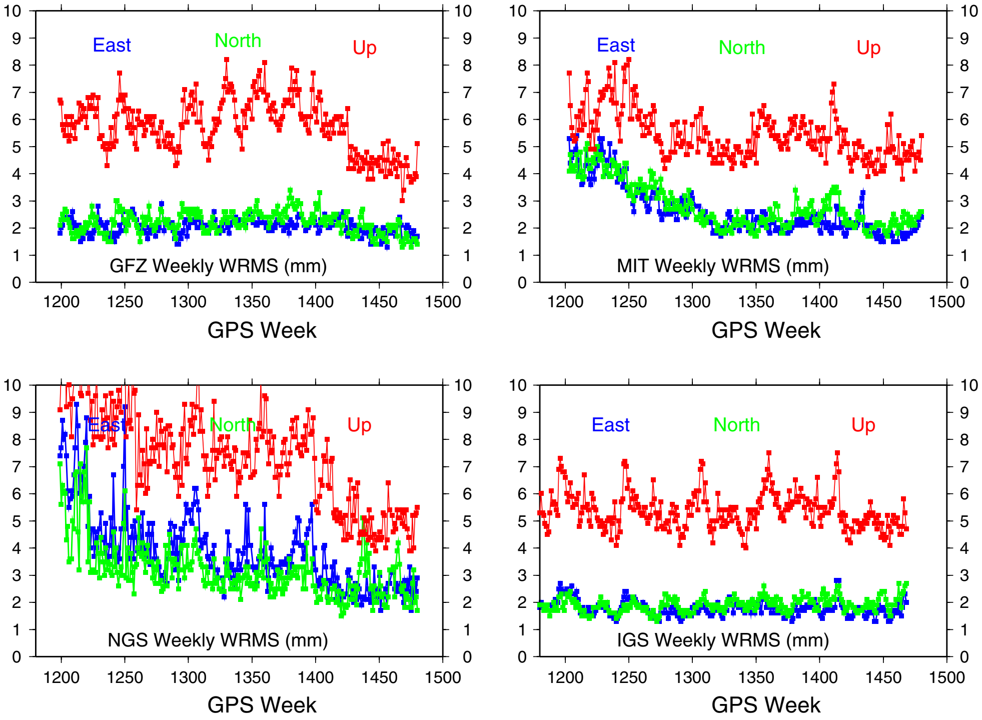

Fig. 2 Internal precision of the IGS weekly solutions

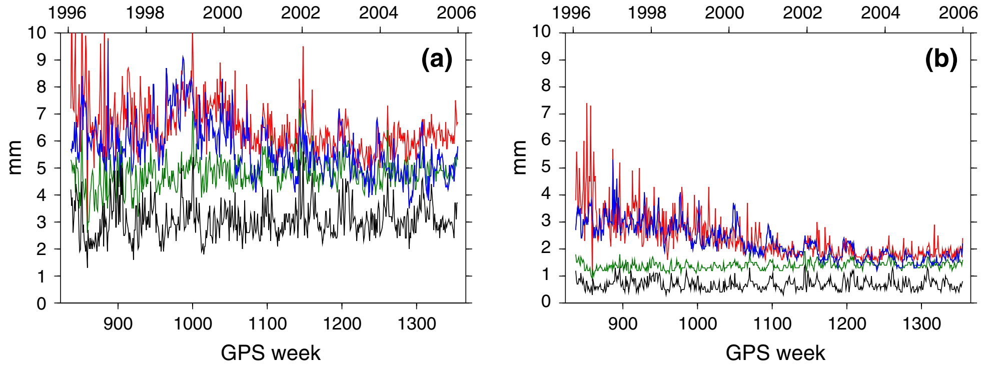

Fig. 3 WRMS estimated from the stacking of real and synthetic station position time series for the vertical (**a**) and the horizontal component (**b**). *Blue* IGS data. *Black* synthetic data based on the loading model only. *Green* synthetic data based on the loading model + flicker noise. *Red* synthetic data based on the loading model + flicker noise + spatially correlated noise

On the basis of a loading model, synthetic position sets have been generated at the real data set epoch using the exact network availability. The loading model has been provided by Tonie van Dam (University of Luxembourg) and consists of displacement time series in the CF frame (Blewitt 2003) that have been generated using the Green's function approach (van Dam and Wahr 1987; Farrell 1972). It takes into account the atmospheric, non tidal ocean contribution and land water loading effects: more details about the fluid data used and modeling strategy can be found in Collilieux et al. (2008). Although this model is not exact, we have nevertheless observed good correlation at some IGS sites at the annual frequency, so that the order of magnitude of the variations is reasonably correct. The WRMS estimated from the stacking of the synthetic time series is presented in Fig. 3 in black. Note that as a consequence, weekly translations, rotations and scale have been removed from the synthetic station positions. If the loading model used is assumed correct, the horizontal and vertical WRMS would be smaller than they are actually estimated, at the level of 0.7 and 3.0 mm, respectively for the horizontal and vertical. The difference would consequently be due to GPS noise. To study this assumption, we have added the contribution of some noise processes in the synthetic data set.

Flicker noise processes contribution has been added to the synthetic data since widely detected in GPS station position time series (Zhang et al. 1997). Such processes are parameterized by a variance level that has been chosen here according to Williams et al. (2004) empirical variance latitude dependent model derived from their Fig. 6b. These estimated values have been shown to be overestimated mostly due to the presence of anomalous harmonics in GPS position time series (Ray et al. 2007) and short memory time correlated processes that were not considered in the analysis of Williams et al. (2004). These values have been consequently scaled by 60% according to the conclusion of Amiri-Simkooei et al. (2007) to generate time correlated noise. The derived WRMS are shown in green on Fig. 3. The introduction of the flicker noise background approximately doubles the levels of WRMS of the synthetic data. Finally the Gaussian spatially correlated noise has been added on the basis of the IGS variance-covariance matrices. These have been scaled beforehand by a factor of 25% according to a scaling factor based on IGS residual height time series analysis, as estimated by Collilieux et al. (2007). They are shown in red on Fig. 3. The derived WRMS time series actually reproduce quite faithfully the IGS WRMS estimated values. The rather good agreement explicitly shows that the information supplied in the IGS covariance matrix is reliable, notably on the vertical, since variations of the synthetic data WRMS faithfully reproduce observed variations (see the bump around 1999–2000 on the height component). It also points out that the seasonal pattern observed in the WRMS may be related to loading effects.

This experiment gives an estimation of the lowest GPS station position repeatability that could be achieved. It could reasonably be close to 3 mm in vertical and 1 mm in horizontal. The observed difference to this value might be attributed to remaining noise processes that are either time or spatially correlated. The published values for their variance level seem to explain the observed differences. Of course, results of such simulations should be interpreted with caution since they result from one noise realization. Moreover, the flicker noise variance values that we have used have been taken from the published result of one analysis center solution whereas the IGS is a combined solution. They have also been estimated by taking into account the crustal motion related to loading effects that mostly occur at the annual and semi-annual frequency. Although this study has some limitations also related to the loading model accuracy, it may help understanding statistics that are often encountered in reference frame analysis and could be used to test loading and noise model adequacy with real observations.

4.2 GPS TRF origin and scale

Like any dynamical (satellite) technique, GPS (as SLR and DORIS) should in theory allow a TRF determination with an origin centered at the center of mass of the whole Earth, being the point around which the satellites orbit. The TRF scale should be equivalent, if not the same for all techniques, since it is conditioned by conventional constants as the speed of light and the gravitational constant GM as well as relativistic correction model which are supposedly the same for all techniques (McCarthy and Petit 2004). In reality there are many technique-specific systematic errors which influence the origin and scale parameters. For GPS, the geocenter components are entirely influenced and dominated by orbit mismodeling errors (Hugentobler 2005) whereas the scale is highly dependent on ground and satellite antenna PCV (Ge et al. 2005).

Despite these GPS specific systematic errors, we try here to evaluate how IGS individual analysis centers compare in terms of geocenter and scale. There is no useful geocenter or scale information to retrieve from the IGS combined weekly solutions, because they are nominally aligned to the current ITRF through the seven Helmert parameters (Ferland and Piraszewski 2008). When stacking the individual weekly solutions of GFZ, MIT and NGS, we estimate weekly geocenter and scale components with respect to the ITRF2005. Figure 4 illustrates the three sets of geocenter and the scale parameters for all three analysis centers. From that figure we can see that the temporal geocenter agreement is poor. However we note some good agreement in the Y component for the three ACs, a certain agreement between GFZ and MIT in the X component, especially at the early dates of the plot and some coherence for the three ACs in the Z component after the week 1400 (November 2006).

However, Fig. 4 shows very clear, regular and peculiar seasonal variation in the GFZ Z-translation component, which is most probably connected to some orbit mismodeling defects. The Z geocenter component exhibits the highest variations. Although it is not as clear as in the scale parameter due to the presence of periodic signals, there is an offset of approximately 1.4 cm after the week 1400. A spectral analysis of this time series after the removal of the offset has been conducted following Collilieux et al. (2007). The spectrum represented in Fig. 5 shows the presence of a wide annual spike with a maximum at 1.08 cycles per year with about 13.8 ± 0.3 mm of amplitude. A semi-annual signature is also detected at the level of 4.8 ± 0.3 mm. These values are too large to be attributed to the true geocenter motion (Collilieux et al. 2008). Some harmonics of the draconitic GPS year frequency, previously detected in GPS time series by Ray et al. (2007), Amiri-Simkooei et al. (2007), Collilieux et al. (2007), are clearly seen on that component. They highlight the presence of a purely non-harmonic signal with a frequency of 1.04 cycles per year.

Regarding the GPS scale, Fig. 4 indicates a piece-wise behavior for the three ACs, as a function of the underlying reference frame used in the IGS processing: IGS00 up to January

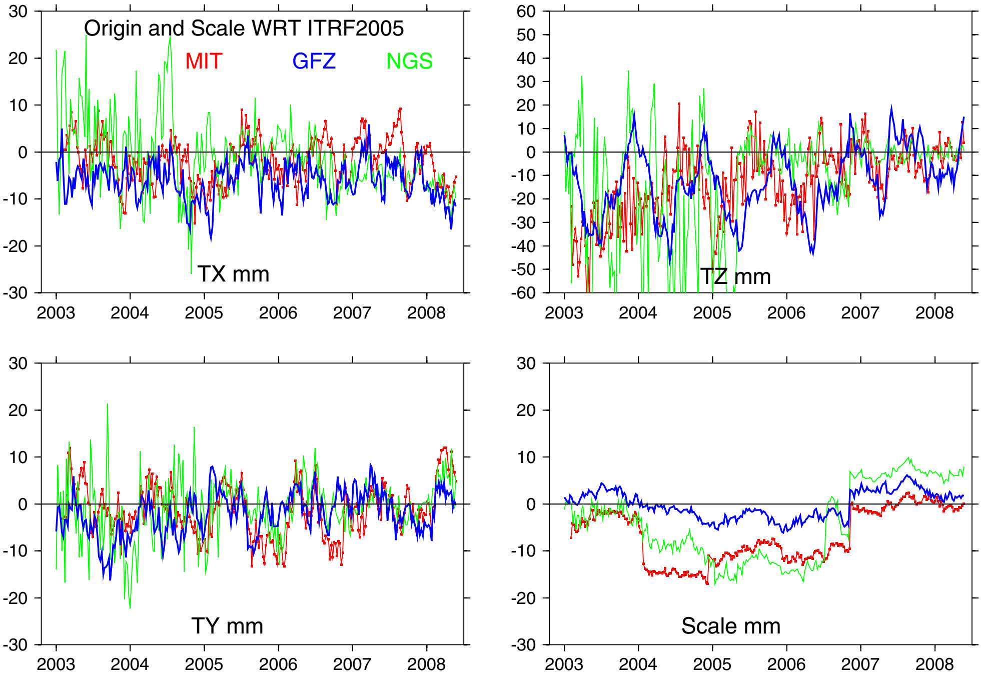

Fig. 4 Origin and scale of GFZ, MIT and NGS with respect to ITRF2005

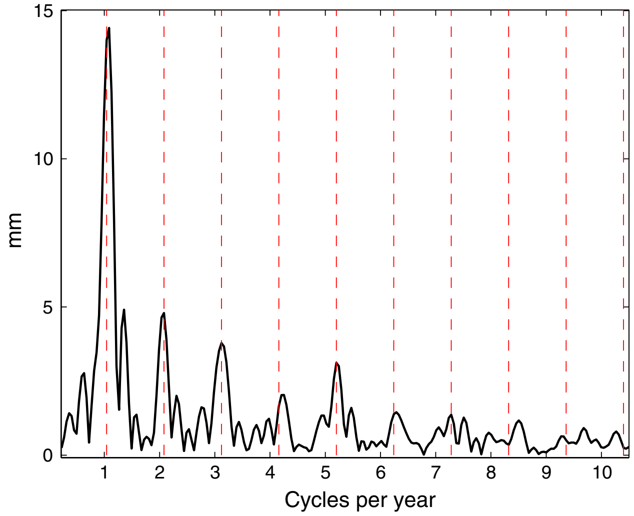

Fig. 5 Amplitude spectrum of GFZ Z-translation component. The *vertical dashed lines* indicates the harmonics of the frequency 1.04 cycles per year

2004, IGb00 since then until the GPS week 1400 (November 2006) and the currently used IGS05. These results confirm the fact that the GPS scale is highly dependent on the PCV correction model, being constructed with fixed ITRF scale. We note however a good agreement at the level of 0.5 ppb (3 mm at the equator) between the three ACs during the period 2003 up to January 2004, large discrepancies between January 2004 and November 2006 and a very striking similar behavior with the currently used IGS05 frame and absolute PCV model.

4.3 IGS network and its effect

The GPS network of the IGS is by far the most dense of the four techniques, but with unbalanced distribution between the northern and southern hemispheres. For instance, among the 258 IGS sites included in the ITRF2005, 202 sites are located in the northern hemisphere, whereas only 56 sites are located in the southern hemisphere. The usage of the minimum constraints approach when stacking the weekly IGS solutions involves an external reference frame in which the obtained long-term cumulative solution is expressed. We used the ITRF2005 as the external frame, restricted to 100 sites selected from the current RF sites of the IGS05. We then varied the RF sites by dropping ten sites, but keeping the global coverage between the two hemispheres. In order to evaluate the network long-term effect, we compared the two series of polar motion obtained in these two test combinations. The differences in X and Y components of polar motion are illustrated by Fig. 6 where we can see that the network effect introduces a drift of 2 and 1 micro-arc-seconds (µas) per year in X and Y, respectively. Note that the 2 µas are considered here as the level of precision (as opposed to accuracy) of consistency of the GPS EOPs with the combined frame. This high level of precision is only possible thanks to the well distributed IGS sites used in these analyses. Similar analysis with VLBI or SLR data and networks would lead

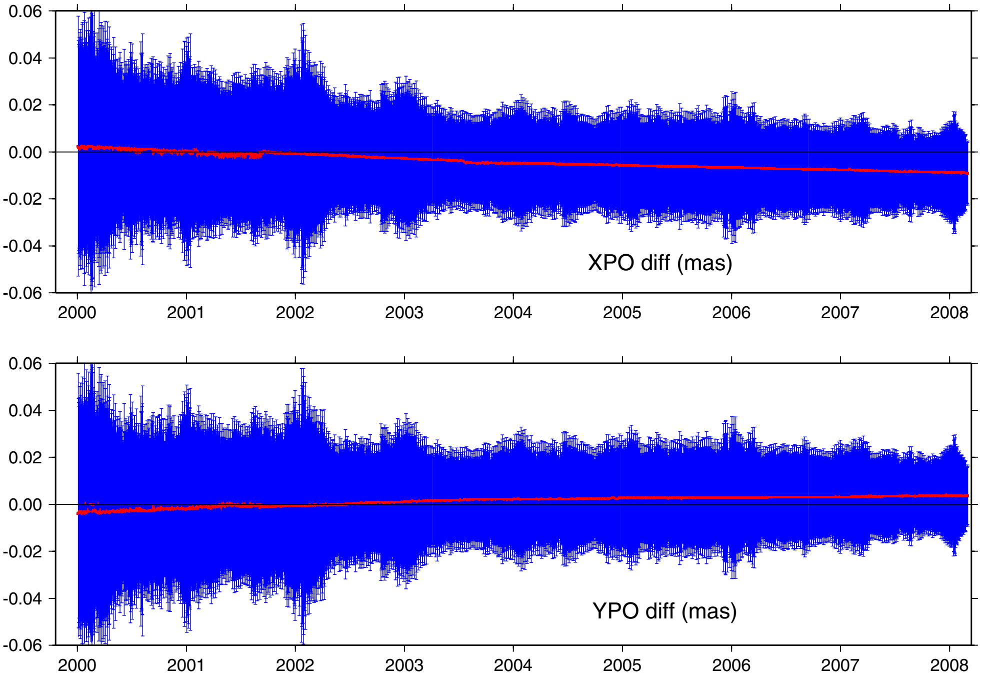

Fig. 6 Polar motion differences between two combinations where the number of reference frame stations differ by 10

to an effect at least ten times worse than in case of GPS. As for the EOP accuracy, we refer to the ITRF2005 results and use the WRMS values as indicators of the EOP quality of the four technique solutions used in the ITRF2005 which range from 50 µas for GPS to 130 µas for VLBI and SLR and about 700 µas for DORIS (Altamimi et al. 2008).

5 Conclusion

This paper reviews and evaluates the importance of the GPS/IGS contribution to the ITRF. The discussion is essentially based on the necessity and requirement for a stable and reliable reference frame for the benefit of both the ITRF and the IGS frame and its products. The unprecedent level of GPS positioning performance (2 mm horizontal and 5 mm vertical, at the weekly sampling) is entirely due to the involvement of multiple IGS analysis centers. This level of precision underlines, however, not only the strengths, but also the weaknesses of GPS level of accuracy, especially in terms of the reference frame requirements. From this point of view, the major weaknesses are the station position discontinuities due to equipment change and the unsecured IGS reference frame stations, the essential basis for the long-term maintenance of the reference frame. The imprecise GPS frame origin seems to be completely due to orbit modeling defects, and hence needs more analysis and refinement by the IGS analysis centers. The high amplitude harmonic signals found in the GFZ Z-translation component is most likely to be due to the correlation between the orbit errors and geocenter components. The GPS TRF scale, however, seems to be more difficult to improve, being dependent on the antenna PCV and cannot be separated from the satellite antenna offset effect if that is not already known very accurately a priori. Today the GPS TRF scale seems to be more stable after the IGS introduction of the absolute PCV model at GPS week 1400, as judged from the three time series we analyzed (GFZ, MIT and NGS). A stable GPS TRF scale, i.e., with no drift in time is critical, otherwise this would lead to spurious or unrealistic vertical station velocities. Despite these weaknesses, the strengths of GPS, due in large part to the IGS AC efforts are enormous and of great benefit to the ITRF. These include the most precise polar motion of the four ITRF techniques, the strengthening of the link between SLR and VLBI networks, the geographic coverage and dense IGS network allowing for, with the usage of the IGS products, a variety of geophysical and other geoscience applications, as well as the precise access to the ITRF anywhere, anytime. Finally, at the time of writing, with the involvement of most of the analysis canters, the IGS is undertaking a great effort of reprocessing the entire time span of the GPS observations with the aim to produce a long term homogeneous time series. Preliminary analysis of some reprocessed solutions, not addressed here, indicates a high performance of these solutions which will play a significant role in the next ITRF release.

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