Status of the ITRF development and SLR contribution

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Abstract

It is expected to start preparing for a new version of the International Terrestrial Reference Frame, namely the ITRF2008. Before initiating this new solution, some conditions have to be satisfied, mainly the need of reprocessed and consistent solutions from each technique: a new reprocessed IGS solution involving the absolute PCV models, an improved reanalysis solution from IVS accounting for the mean pole tide correction and better troposphere modeling, an improved ILRS solution taking into account all range biases and other station-dependent corrections, and new DORIS solutions where improvements are expected in the frame Z translation and the scale. In preparation of the ITRF2008, we analyze here individual SLR and the IVS regular time series solutions of station positions. A particular emphasis is given to the time behavior of the frame physical parameters (origin and scale). In an attempt to evaluate the pertinence of the estimated vertical velocities of SLR and VLBI stations co-located with GPS, we confront both estimations to GIA model predictions. This confrontation suggests poor agreement between the model predictions and space geodesy estimates on a site-by-site basis.

Introduction

The science requirement for the reference frame is to have an ITRF that is stable at the level of 0.1 mm/yr. The notion of stability used here is that the frame parameters and, in particular, its origin and scale should have linear behavior with no discontinuity over the time-span of the implied observation. The power of using time series of station positions as input data for the ITRF formation is that they allow the assessment of the time behavior of its defining parameters, notably the origin and the scale. Without being exhaustive, one example of Earth science applications of the reference frame is the mean sea level rise and its variability. Therefore any bias in the ITRF scale or origin will directly map to the mean sea level estimation through the usage of the ITRF data [Beckley et al, 2007, Morel and Willis, 2005].
The Satellite Laser Ranging technique is essential to the ITRF, being used to define its origin and contributing to the definition of its scale. In view of the ITRF2008, we present in the following sections analysis of some preliminary SLR and VLBI solutions and focus mainly on their origin and scale behavior. We also evaluate the station vertical velocities, as determined by some of these solutions and perform confrontation to Glacial Isostatic Adjustment model ICE-5G VM4 of Peltier (2004), [SBL 2005, Peltier, 2004].

Input data

We use the following time series solutions provided in SINEX format and which were available at the time of the ILRS workshop:

- IVS routine solutions sampled at the regular 24-hour sessions;
- SLR time series: ASI-12, GRGS-11, NCL test solutions from Philip Moore (private communication) and three IGN tests solutions (computed by the 3rd author of this paper) using data from separately Lageos I, Lageos II, and both satellites.

Data analysis

We use the CATREF software approaches of (1) internal or intrinsic conditions and (2) minimum constraints when stacking the various time series (Altamimi et al., 2007). The first approach allows indeed preserving the intrinsic origin (of SLR) and the scale (of SLR and VLB), by taking the mean of the analyzed time series of station positions, imposing neither shift nor drift of these parameters. In this case, the weekly translation and scale parameters are estimated with respect to the long-term averaged origin and scale of the accumulated solution. The second approach permits not only the expression of the long-term accumulated solution in a given reference frame, but also the estimation of the weekly transformation parameters with respect to the selected external reference frame.

Origin and scale analysis

Figure 1 displays the annual averages of the translations and scale factors with respect to ITRF2005, where good agreement between the three analyzed solutions can be noticed. We see in particular the origin consistency with the ITRF2005, whereas the scale behavior exhibits a significant drift.

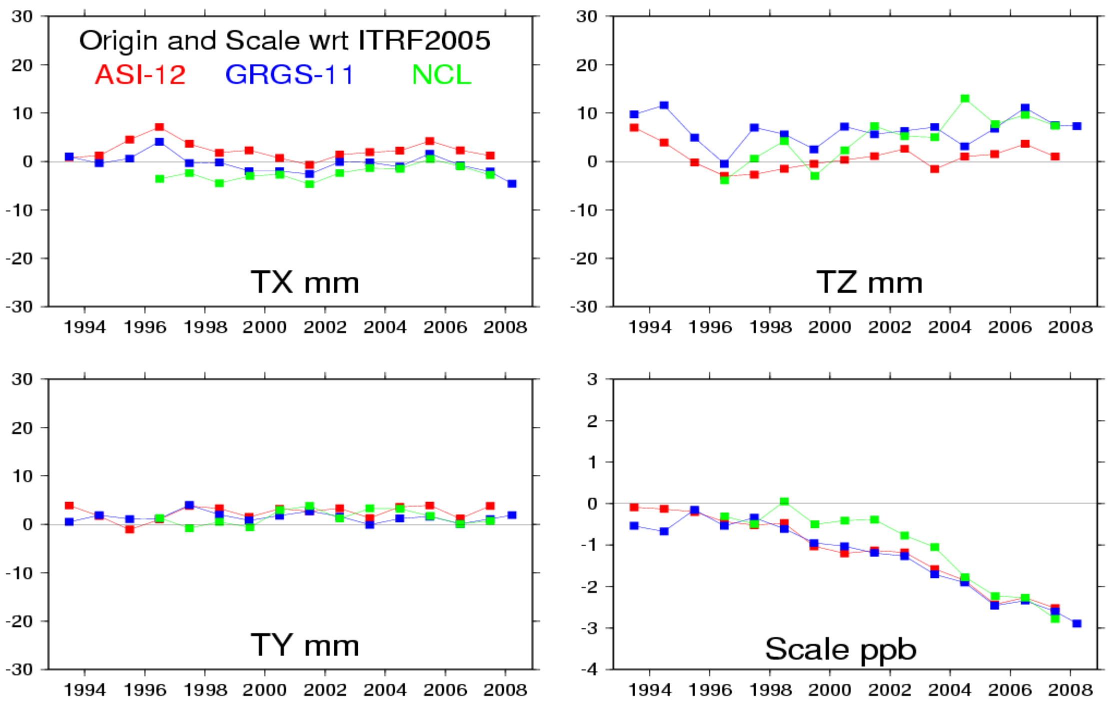

Figure 1. Averaged annual origin components and scale factors of the analyzed solutions with respect to ITRF2005

Figure 2 shows the averaged annual origin parameters and scale factors with respect to the ITRF2005 of the three solutions determined using separately data from Lageos I, Lageos II, and data from both satellites. This figure demonstrates that these parameters are roughly the same for either satellites (taken separately) or their combination.

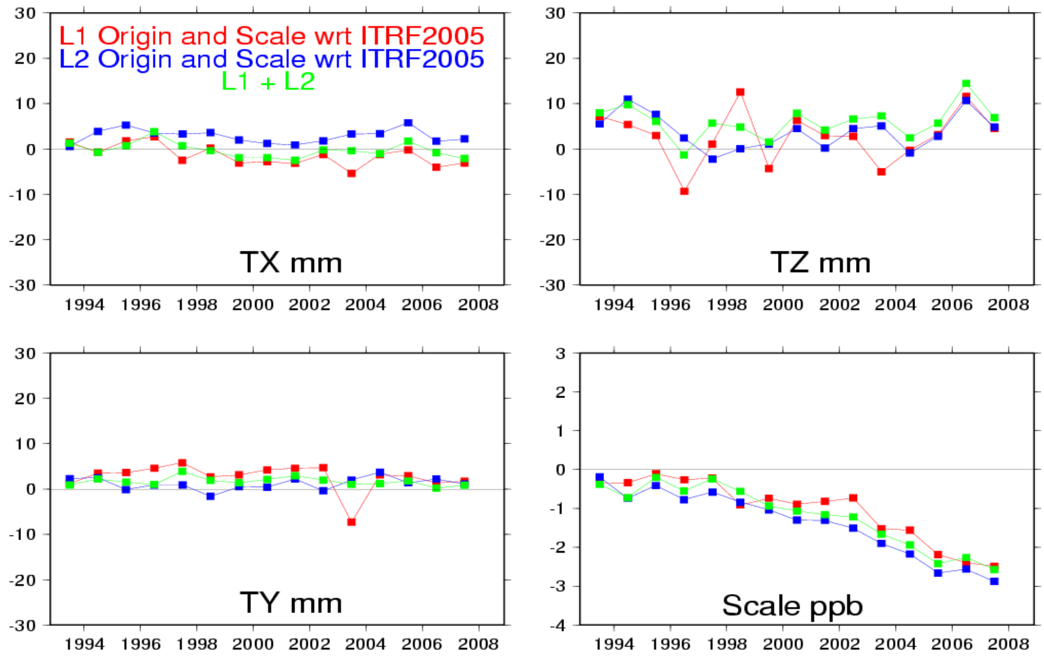

Figure 2. Averaged annual origin components and scale factors of three solutions determined using data from Lageos I in red, Lageos II in blue, and both satellites in green

Figure 3 displays the averaged annual scale factors with respect to ITRF2005 for IVS VLBI and SLR ASI-12 time series. We distinctively see the scale factor offset of VLBI solution with respect to ITRF2005 which is due to the fact the IVS is now applying for the mean pole tide correction [McCarthy and Petit, 2003]. The apparent scale drift difference between IVS VLBI and SLR ASI-12 solutions is still to be understood.

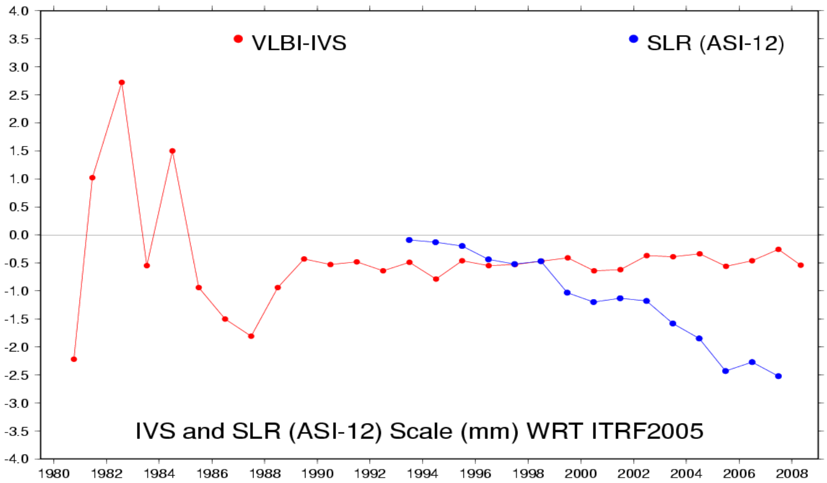

Figure 3. Averaged annual scale factors of VLBI IVS and SLR ASI-12 time series with respect to ITRF2005

Analysis of station vertical velocities

In order to investigate the significance and accuracy of station vertical velocities as estimated by SLR and VLBI, we selected from both networks the core sites that are co-located with GPS as depicted on Figure 4. The reasons for this selection are (1) there are very few sites (7 in total) where VLBI and SLR are co-located; (2) both techniques are co-located with GPS in all sites and (3) the scale and its drift between both techniques are fully determined over these co-located sites. Therefore GPS is playing the important role of connecting the SLR and VLBI networks. The reason for investigating the station vertical velocities is due to their dependency on the frame origin and scale time evolution definition. It could be shown that a drift in the Z-translation (δTz) component produces velocity changes of any site at latitude ϕ by $\delta Tz \times \cos(\phi)$ and by $\delta Tz \times \sin(\phi)$ along the north and vertical directions, respectively (Altamimi et al, 2007). On the other hand, any scale drift introduces vertical velocity changes with one-to-one ratio.

Supposedly, if the scale determined by both techniques is accurate and has no drift or discontinuities, and in the absence of systematic errors, there should be no physical reason of significant difference between both scale estimates. However, given the different natures of the shapes of both networks (see Figure 4), sampling the crust vertical motion in two different ways, this network effect might be one cause, among others, of the scale rate difference between the two technique solutions. The intrinsic conditions were used over the origin and the scale to generate the SLR ASI-12 long term solution. As the VLBI frame cannot be formed without inheriting its origin from SLR, two long-term VLBI solutions we generated by stacking the time series, and are expressed in the ITRF2005 and ITRF2000 origins, respectively, whereas the scale is determined by the intrinsic conditions.

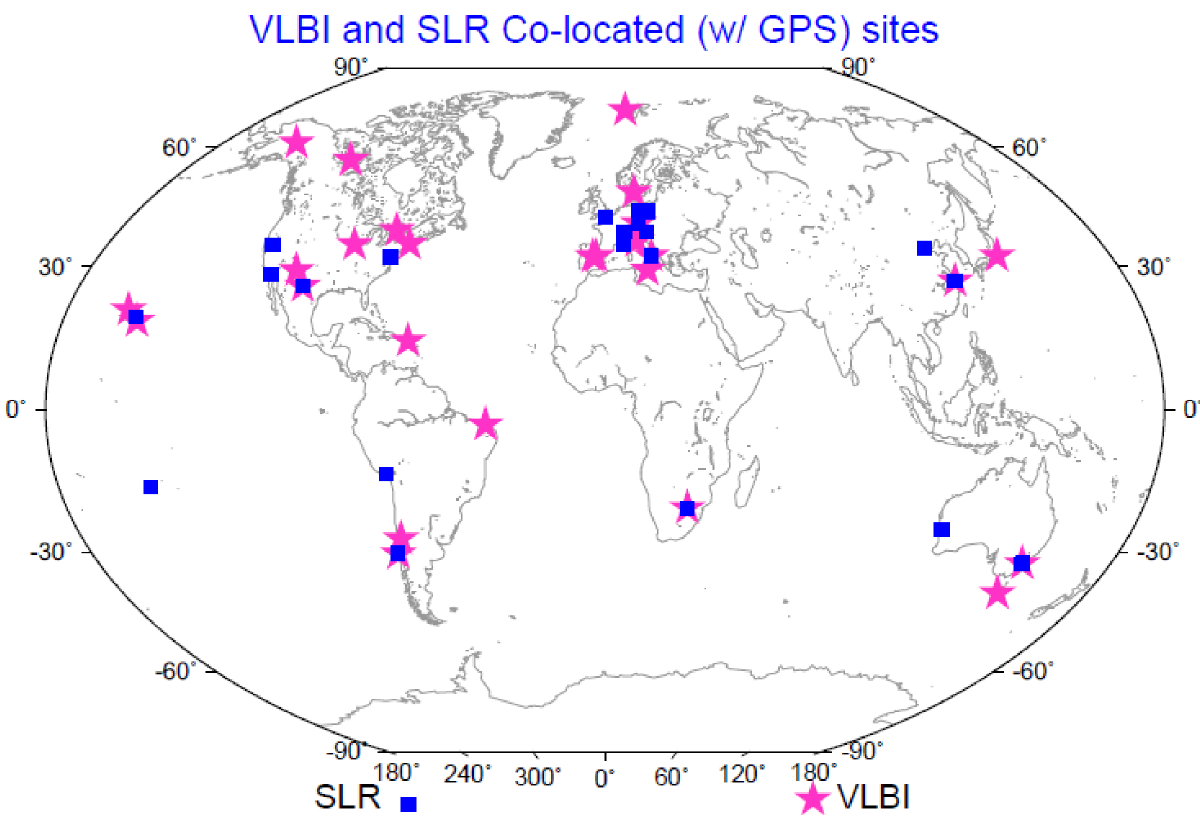

Figure 4. VLBI and SLR sites co-located with GPS

In order to evaluate the pertinence of the estimated vertical velocities by both technique solutions (VLBI IVS and SLR ASI-12), we attempted to confront them to the GIA model of Peltier (2004). Figure 5 depicts the SLR ASI-12 station vertical velocities corrected by the predictions of the GIA model, whereas Figures 6 and 7 show the GIA-corrected vertical velocities of the VLBI sites, expressed in the ITRF2005 and ITRF2000 origins, respectively.

If the GIA model and space geodesy estimates were perfect, with the assumption that all station vertical velocities are only due to GIA, correcting the station vertical velocities by the model predictions would lead to zero velocities at all sites. From Figures 5, 6 and 7, it becomes clear that on a site-by-site basis, not all the sites have zero vertical velocities after GIA model corrections. However, we computed the weighted means of the uncorrected and GIA-corrected vertical velocities of both co-located (via GPS) networks and reported these values in Table 1. The reasons for computing these averages are that they represent the mean vertical motions of each network and because of their possible correlations with the scale rate estimation. From these values we can notice that GIA corrections induce a mean change of +0.4 mm/yr for SLR and VLBI (expressed in ITRF2005 origin) solutions, whereas the change is about -0.4 mm/yr for VLBI solution expressed in ITRF2000 origin. We also notice that expressing the VLBI solution in the ITRF2000 origin reduces significantly the weighted mean of the vertical velocities. Therefore the reference frame stability in origin and scale definition is probably not better than 1 mm/yr, which corresponds to about 0.17 ppb/yr in scale rate.

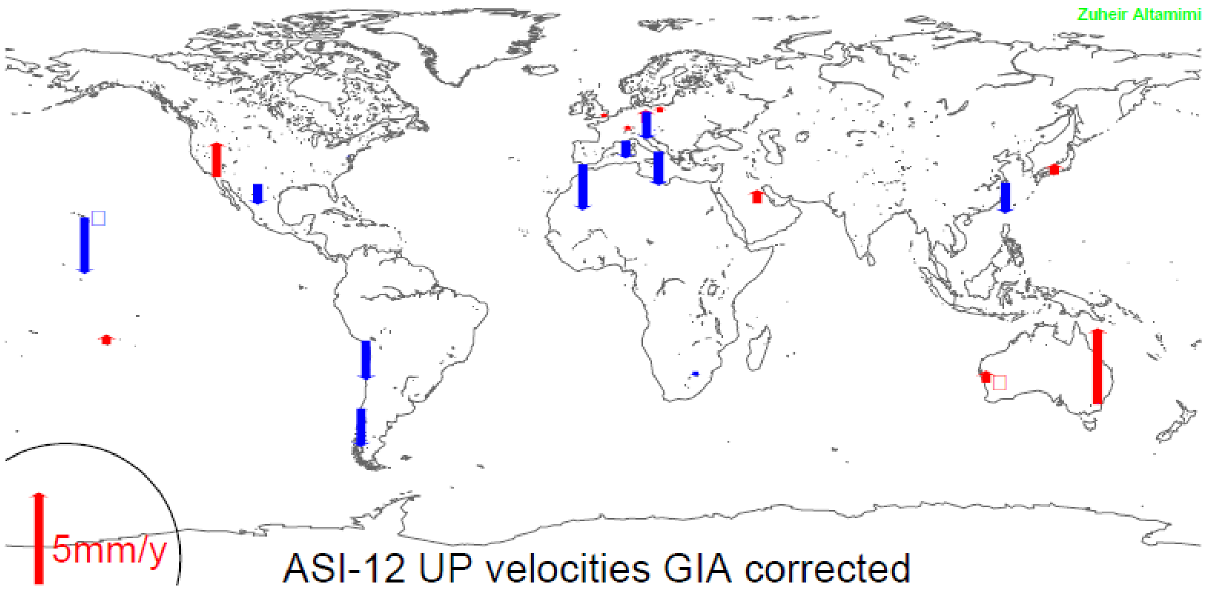

Figure 5. Vertical velocities of ASI-12 SLR core network, corrected by ICE-5G V1.2 GIA model of Peltier (2004). Red vectors represent positive velocities and blue vectors negative velocities.

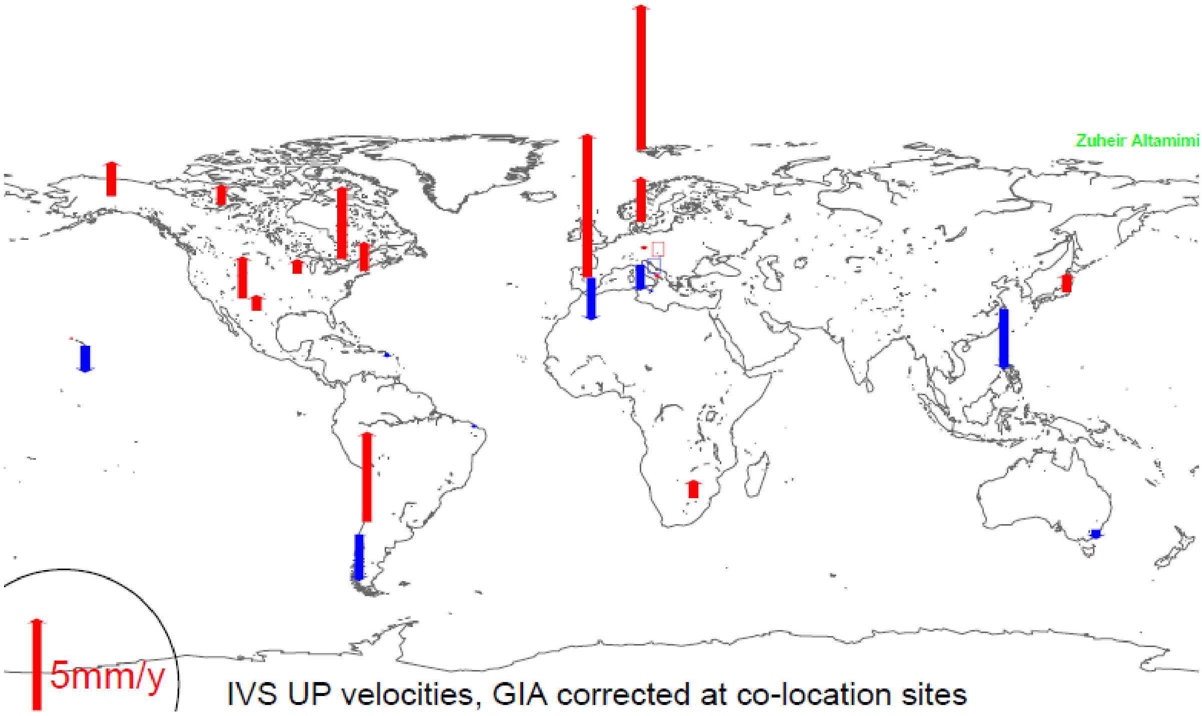

Figure 6. Vertical velocities of IVS-VLBI (intrinsic scale and ITRF2005 origin) co-located stations, corrected by ICE-5G V1.2 GIA model of Peltier (2004). Red vectors represent positive velocities and blue vectors negative velocities.

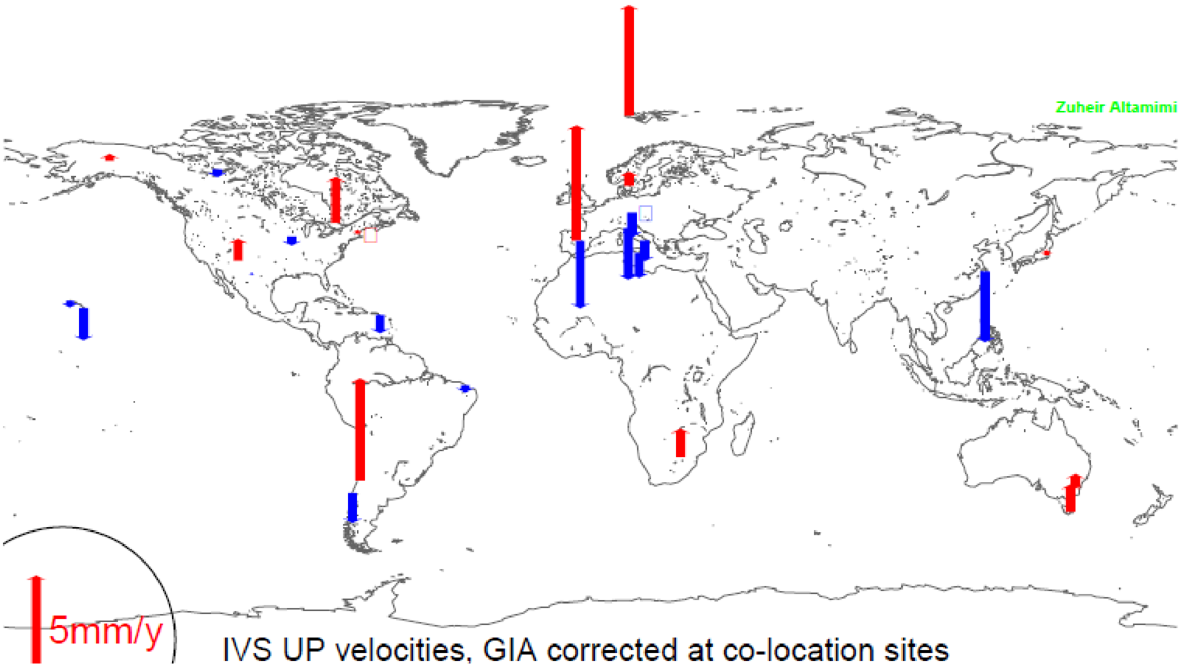

Figure 7. Vertical velocities of IVS-VLBI (intrinsic scale and ITRF2000 origin) co-located stations, corrected by ICE-5G V1.2 GIA model of Peltier (2004). Red vectors represent positive velocities and blue vectors negative velocities.

Table 1. Weighted mean of vertical velocities

	Weighted Mean of Vertical Velocities (GIA not corrected) (mm/yr)	Weighted Mean of Vertical Velocities (GIA corrected) (mm/yr)
SLR ASI-12 (intrinsic origin and scale)	-0.24	+0.16
VLBI IVS (intrinsic scale and ITRF2005 origin)	+0.89	+1.26
VLBI IVS (intrinsic scale and ITRF2000 origin)	+0.19	-0.24

Conclusion

We presented in this paper some preliminary analysis in preparation of the upcoming ITRF2008. We evaluated the origin and scale temporal behaviors of individual SLR and the regular IVS solutions of time series of station positions. Based on these preliminary analyses, we expect no significant change of the ITRF2008 origin, compared to ITRF2005. The difference in scale rate between VLBI and SLR solutions is still to be investigated and understood. Confronting the station vertical velocities estimated by both technique solutions to the predictions of the GIA model of Peltier (2004) yielded poor agreement between the two estimates on a site-by-site basis. The difference between the weighted averages of vertical velocities of VLBI and SLR network solutions is about 1 mm/yr, suggesting the same level of the scale and origin stability of the reference frame.

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