

4 ITRF2014 results

4.1 ITRF2014 origin and scale

The submitted ILRS SLR solution was used to define the ITRF2014 origin, by fixing to zero (and consequently eliminating from the normal equation) the 6 parameters (translations and rates) of its corresponding long-term cumulative solution. The long-term intrinsic origin of the latter is preserved via the usage of internal constraints [Altamimi et al., 2007], over the time span 1993.0-2015.0.

An estimate of the translation components between ITRF2014 and ITRF2008 showed small translation components at epoch 2010.0, namely 1.6, 1.9 and 2.4 mm, along the three axes X,Y,Z, respectively. The translation rates are statistically zero over the three components. These results are an indication of the level of the ITRF origin stability achievable today using SLR data, dominated by LAGEOS I and II observations [Luceri and Pavlis, 2016].

The ITRF2014 scale is specified by the average of VLBI and SLR scales, i.e. ITRF2014 scale is defined to be in the middle of the scales of VLBI and SLR long-term solutions. This choice is justified by the fact that we do not have any means to discriminate between the two technique solutions and therefore their simple average is a fair choice that minimizes the scale impact for these two techniques when using the ITRF2014 products. The result of the final ITRF2014 combination showed then a scale factor between VLBI and SLR solutions of 1.37 (± 0.10) ppb at epoch 2010.0 and a scale rate of 0.02 (± 0.02) ppb/yr. The ITRF2014 results regarding the level of the scale agreement between SLR and VLBI confirm the ITRF2008 finding and are an indication of the persistent scale offset between the two technique solutions.

4.2 ITRF2014 products

The ITRF2014 main products are:

- Station positions at epoch 2010.0 and velocities. These values are split into four tables corresponding to the four techniques: VLBI, SLR, GPS and DORIS. They are also provided in SINEX files with full variance covariance information. All the corresponding files are available through the ITRF2014 web and ftp sites. See next Chapter for access to these files.
- The Post-Seismic Deformation parametric models which are an integral part of the ITRF2014 products. The users should then

be aware that they must compute the model corrections, using the equations supplied in Appendix C of [Altamimi et al. \[2016\]](#), see [Appendix 2](#), to be then added to the ITRF2014 coordinates if the needed position epoch occurs during the post-seismic relaxation period. Failing to do so would introduce position errors at the decimeter level for many stations impacted by PSDs. More information and some useful subroutines in Fortran are provided at the ITRF2014 web site:

http://itrf.ign.fr/ITRF_solutions/2014/.

- Earth orientation parameters. Consistent series of polar motion and its daily rates, universal time (UT1–UTC) and Length of Day (LOD), with the latter being determined by VLBI uniquely. The reason for using LOD values from VLBI only is to avoid contaminating the VLBI estimates by biased determinations from satellite techniques. The EOP series are also available through the ITRF2014 web and ftp sites (see below).

4.3 Transformation parameters between ITRF2014 and ITRF2008

For many applications and in order to ensure the link between ITRF2014 and ITRF2008, it is essential to assess consistently the transformation parameters between the two frames. The same 127 stations displayed in [Figure 2](#) that were used to ensure the alignment of the ITRF2014 orientation and rate parameters to the ITRF2008, were also used to estimate the transformation parameters between the two frames. The main criterion for the selection of these 127 stations were (1) to have the best possible site distribution; (2) to involve as many as possible VLBI, SLR, GNSS and DORIS stations and (3) to have the best agreement between the two frames in terms of post-fit residuals of the 14-parameter transformation. Regarding this third criteria, the WRMS values of the 14-parameter similarity transformation fit are 1.8, 1.6 and 2.4 mm in position (at epoch 2010.0) and 0.2, 0.2, 0.3 mm/yr in velocity, in East, North and Vertical components, respectively. [Table 2](#) lists the transformation parameters from ITRF2014 to ITRF2008, to be used with the transformation formula given by equation (6).

$$\left\{ \begin{array}{l} \begin{pmatrix} x \\ y \\ z \end{pmatrix}_{i08} = \begin{pmatrix} x \\ y \\ z \end{pmatrix}_{i14} + T + D \begin{pmatrix} x \\ y \\ z \end{pmatrix}_{i14} + R \begin{pmatrix} x \\ y \\ z \end{pmatrix}_{i14} \\ \begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \end{pmatrix}_{i08} = \begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \end{pmatrix}_{i14} + \dot{T} + \dot{D} \begin{pmatrix} x \\ y \\ z \end{pmatrix}_{i14} + \dot{R} \begin{pmatrix} x \\ y \\ z \end{pmatrix}_{i14} \end{array} \right. \quad (6)$$

where $i08$ designates ITRF2008 and $i14$ ITRF2014, T is the translation vector, $T = (T_x, T_y, T_z)^T$, D is the scale factor and R is the matrix containing the rotation angles, given by

$$R = \begin{pmatrix} 0 & -R_z & R_y \\ R_z & 0 & -R_x \\ -R_y & R_x & 0 \end{pmatrix}$$

The dotted parameters designate their time derivatives. The values of the 14 parameters are those listed in Table 2. Note that the inverse transformation from ITRF2008 to ITRF2014 follows by interchanging ($i14$) with ($i08$) and changing the sign of the transformation parameters.

Table 2: Transformation Parameters at epoch 2010.0 and their rates from ITRF2014 to ITRF2008, to be used with equation (6)

	T_x	T_y	T_z	D	R_x	R_y	R_z
	mm	mm	mm	ppb	mas	mas	mas
	\dot{T}_x	\dot{T}_y	\dot{T}_z	\dot{D}	\dot{R}_x	\dot{R}_y	\dot{R}_z
	mm/y	mm/y	mm/y	ppb/y	mas/y	mas/y	mas/y
	1.6	1.9	2.4	-0.02	0.00	0.00	0.00
±	0.2	0.1	0.1	0.02	0.06	0.06	0.06
	0.0	0.0	-0.1	0.03	0.00	0.00	0.00
±	0.2	0.1	0.1	0.02	0.06	0.06	0.06

4.4 Consistency between local ties and space geodesy estimates

One of the most important by-products of the ITRF2014 combination is the assessment of the level of agreement between local ties and space geodesy estimates, through the availability of the post-fit residuals at co-location sites. In case of large discrepancies, discriminating between local ties and space geodesy estimates is a very delicate exercise, because the reasons for these discrepancies could be due to errors in local ties, in space geodesy estimates or in both. However quantifying the level of agreement between the two ensembles is very critical for further investigation and hopefully for identifying the error sources. At co-location sites, not only station position residuals are computed, but also velocity residuals. Therefore in order to take into account velocity disagreements between the technique solutions, it is more effective to compute the tie discrepancies at their measurement epochs.

The complete list of the residuals (or tie discrepancies) is available in [Appendix 1](#). If we count the percentage of sites where the tie discrepancy is less than 5 mm, we find approximately: 42%, 29% and 23% for GNSS-VLBI, GNSS-SLR and GNSS-DORIS, respectively.