The SLR Contribution to the ITRF

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Abstract

Since the beginning of the ITRF activities in 1988, the analysis centers of the Satellite Laser Ranging (SLR) technique contributed significantly to the International Terrestrial Reference Frame (ITRF). Moreover in terms of datum definition, some SLR solutions were used in the origin and scale definition of the ITRF. In this paper we will review the SLR contribution to the ITRF in terms of network, origin, and scale as well as provide a quality assessment. Some aspects related to the optimal establishment of a global reference frame will be examined in the case of the SLR technique, taking into account the reality of its current network configuration. Future ITRF directions will be presented, in particular the inclusion of the Earth Orientation Parameters in the ITRF combination. Some combination tests will be used to discuss the frame parameters.

Introduction

The notion of terrestrial reference systems is a purely mathematical convention (or model) introduced to describe the shape of the physical Earth. Conversely, coordinates are not observable and there is no physical existence to the frame we usually associate to the network shape provided by space geodesy observations. Therefore, the adopted reference frame (which is the practical implementation of a reference system) should not alter the network shape or its physical properties. Minimum constraints approach is found to be an efficient method allowing the de-correlation of the frame and the observation parameters [*Altamimi et al.*, 2002a].

Mathematically, a datum definition of a Terrestrial Reference Frame (TRF) consists in specifying its origin, scale, orientation, and their time evolution. Some of the frame parameters (such as the origin and the scale) are embedded in space geodesy observations. Dynamical techniques, such as Satellite Laser Ranging (SLR), allow access to the Earth Center of Mass (a natural TRF origin), the point around which the satellites orbit.

The origin of the International Terrestrial Reference Frame (ITRF) is heavily dependent on the SLR origin and its scale is usually defined by an average of SLR and VLBI solutions.

SLR Contribution to the ITRF

The most recent ITRF solution, the ITRF2000, includes seven global SLR solutions containing station positions and velocities, with full variance covariance information, provided in SINEX format. The ITRF2000 origin was defined by fixing to zero the translation and translation rate parameters between ITRF2000 and the weighted mean of the SLR solutions of five analysis centers: CGS, CRL, CSR, DGFI and JCET. Its scale was defined by fixing to zero the scale and scale rate parameters between ITRF2000 and the weighted mean of the above five SLR solutions and the VLBI solutions of the analysis centers GIUB, GSFC and SHA. The ITRF2000 technical description and all results are published in [*Altamimi et al.*, 2002b].

Figures 1 and 2 illustrate the translation and scale variations of the included individual solutions.

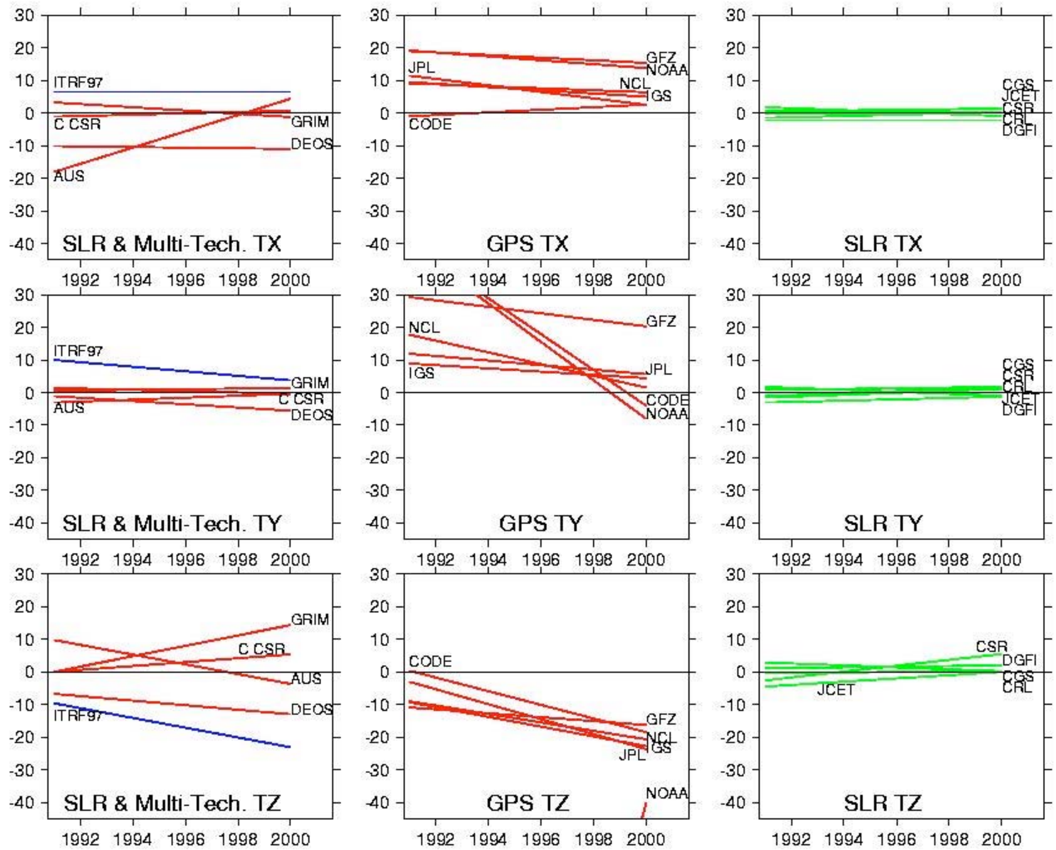

Figure 1. Translation variations (mm) of SLR, Multi-Technique and GPS solutions. The third column plots show the translation variations of the five SLR solutions whose weighted average was used to define the ITRF2000 origin.

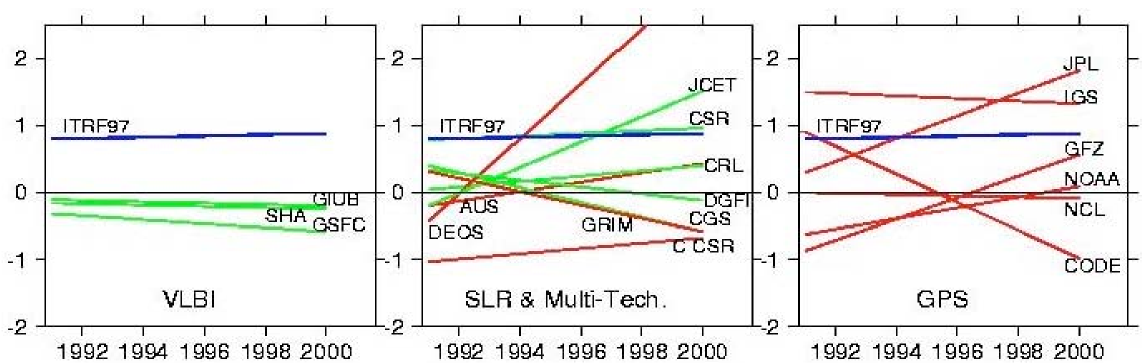

Figure 2. Scale Variations (ppb) of VLBI, SLR, Multi-Technique and GPS solutions. Green lines (grey in b&w version) indicate solutions whose scale weighted average was used to define the ITRF2000 scale. The ITRF97 scale, inserted on these plots, is reduced to the TT-frame.

Simultaneous Combination of Station Positions and Earth Rotation Parameters

In order to be able to combine Earth Rotation Parameters simultaneously with station positions (and velocities), CATREF software was upgraded to include the following equations:

$$\begin{cases} x_s^p = x^p + R2_k \\ y_s^p = y^p + R1_k \\ UT_s = UT - \frac{1}{f} R3_k \\ \dot{x}_s^p = \dot{x}^p + \dot{R}2_k \\ \dot{y}_s^p = \dot{y}^p + \dot{R}1_k \\ LOD_s = LOD + \frac{\Delta}{f} \dot{R}3_k \end{cases}$$

using pole coordinates $\mathbf{x_s^p, y_s^p}$ and universal time $\mathbf{UT_s}$ as well as their daily time derivatives $\mathbf{\dot{x}_s^p, \dot{y}_s^p}$ and **LODs**. $\mathbf{\Delta}$ is one day interval in time unit, considering $\mathbf{LOD = -\Delta \frac{dUT}{dt}}$ and **f** = 1.002737909350795 is the conversion factor from universal to sideral time.

In order to precisely define the datum of the combined frame, minimum constraints equations were implemented in the CATREF software, allowing the expression of the combined solution in any external frame. For more details concerning equations of minimum constraints and their practical use, see for instance *Altamimi et al.*, [2002a].

Analysis of some ILRS Pilot Project Solutions

As first combination tests of the new features of the CATREF software, we used some monthly solutions of the ILRS Pilot Project on “positioning and Earth orientation”.

In order to assess the TRF origin and scale level of agreement of the different SLR solutions, we combined monthly A-solutions of ASI, DGFI and JCET over the year 1999 as well as CSR solutions over 1999-2001. Figure 3 shows the variations of the three translation components and the scale factor with respect to ITRF2000.

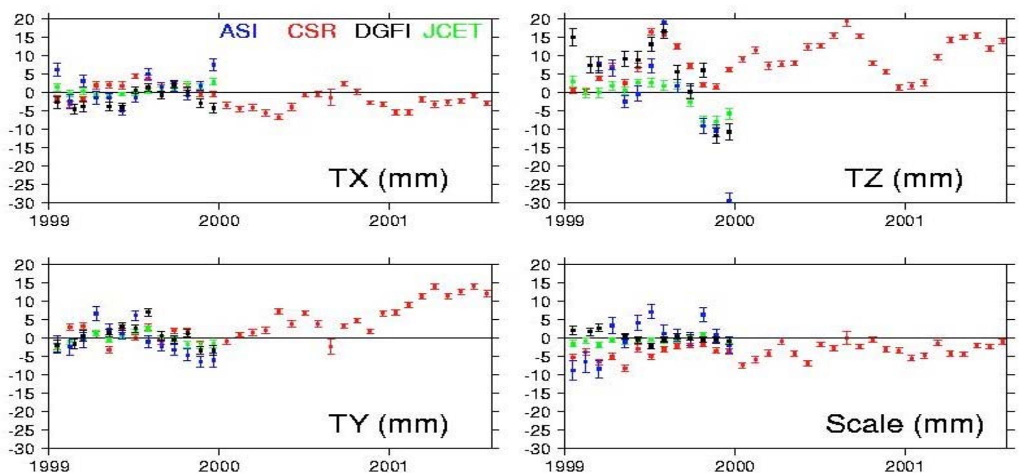

Figure 3. Origin and scale consistency of some ILRS monthly solutions.

Regarding polar motion consistency between the above 4 ILRS analysis centers, Figure 4 illustrates polar motion post fit residuals over the year 1999.

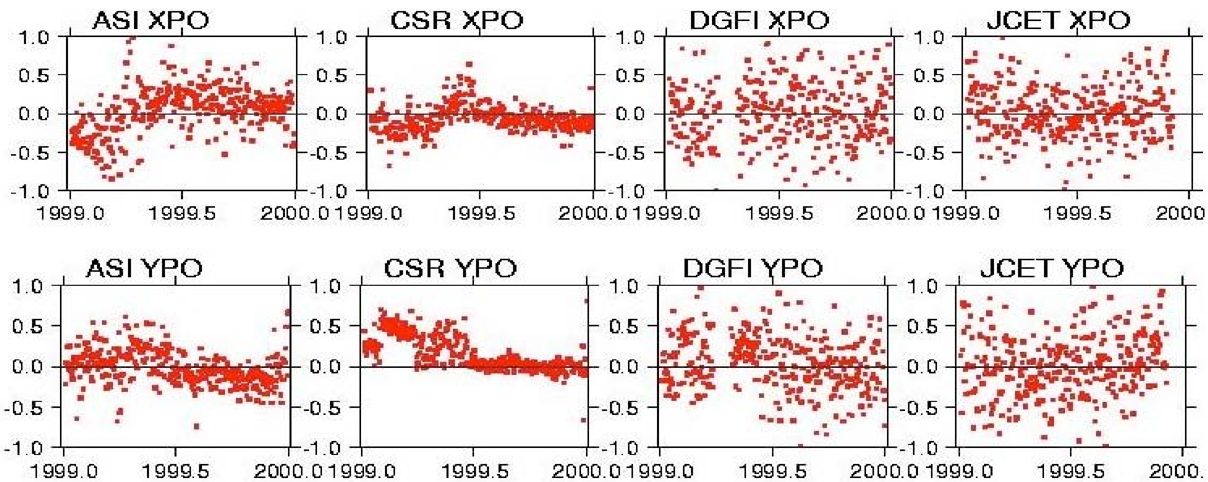

Figure 4. Polar motion residuals (mas) per AC for the year 1999.

On the other hand we combined all the available solutions of the "B"-type, containing epoch polar motion components, as well as their rates for April 2001, taken as an example. Figure 5 shows the corresponding residuals of the different AC solutions.

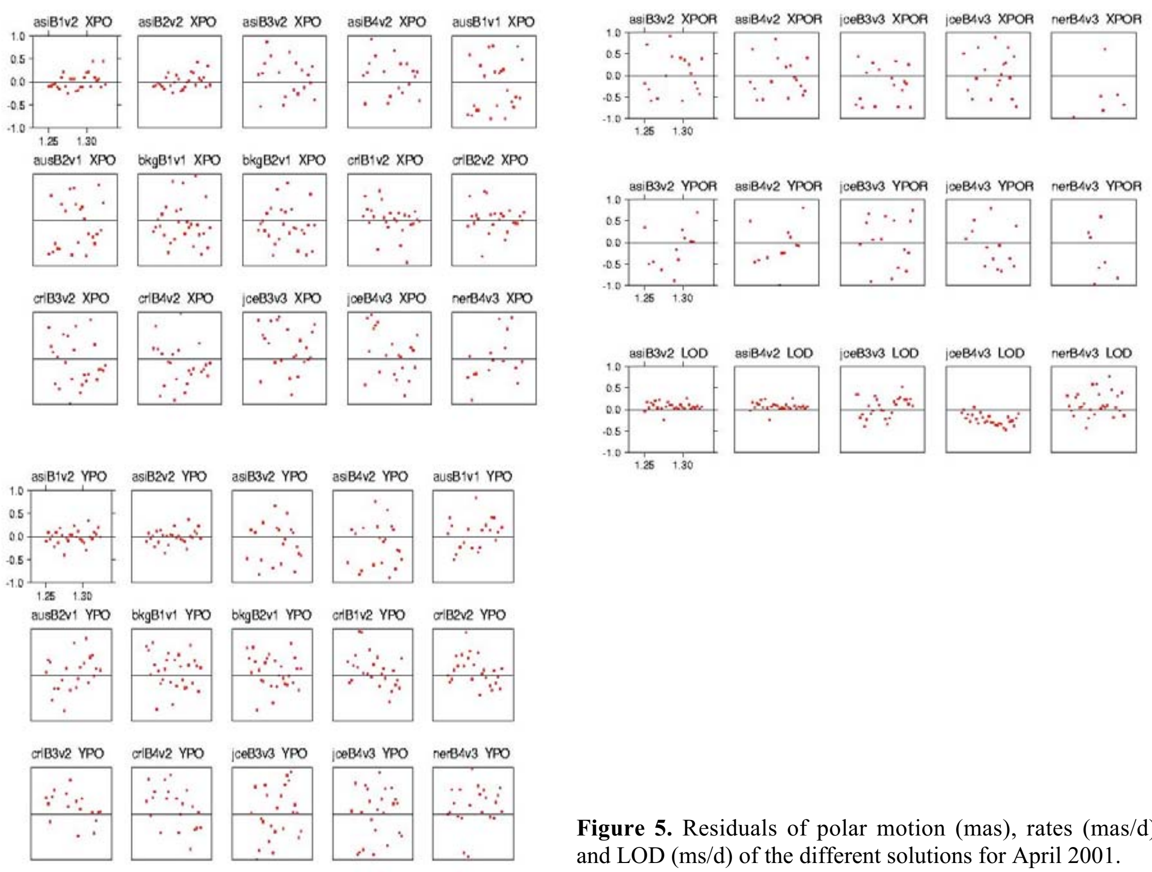

Figure 5. Residuals of polar motion (mas), rates (mas/d) and LOD (ms/d) of the different solutions for April 2001.

Multi-Technique Combination

In order to compare SLR solutions of station positions and EOPs to other technique estimates, we used in addition to ILRS Pilot Project monthly solutions the following solutions covering 1999:

- GPS: IGS weekly combined solutions
- VLBI: GSFC 24h-session SINEX files
- DORIS: IGN/JPL weekly solutions

As the number and distribution of the collocation sites between the four techniques have their impact on the combination, Figure 6 illustrates the distribution of the per-technique collocation sites, showing, in particular, the poor SLR/VLBI collocation.

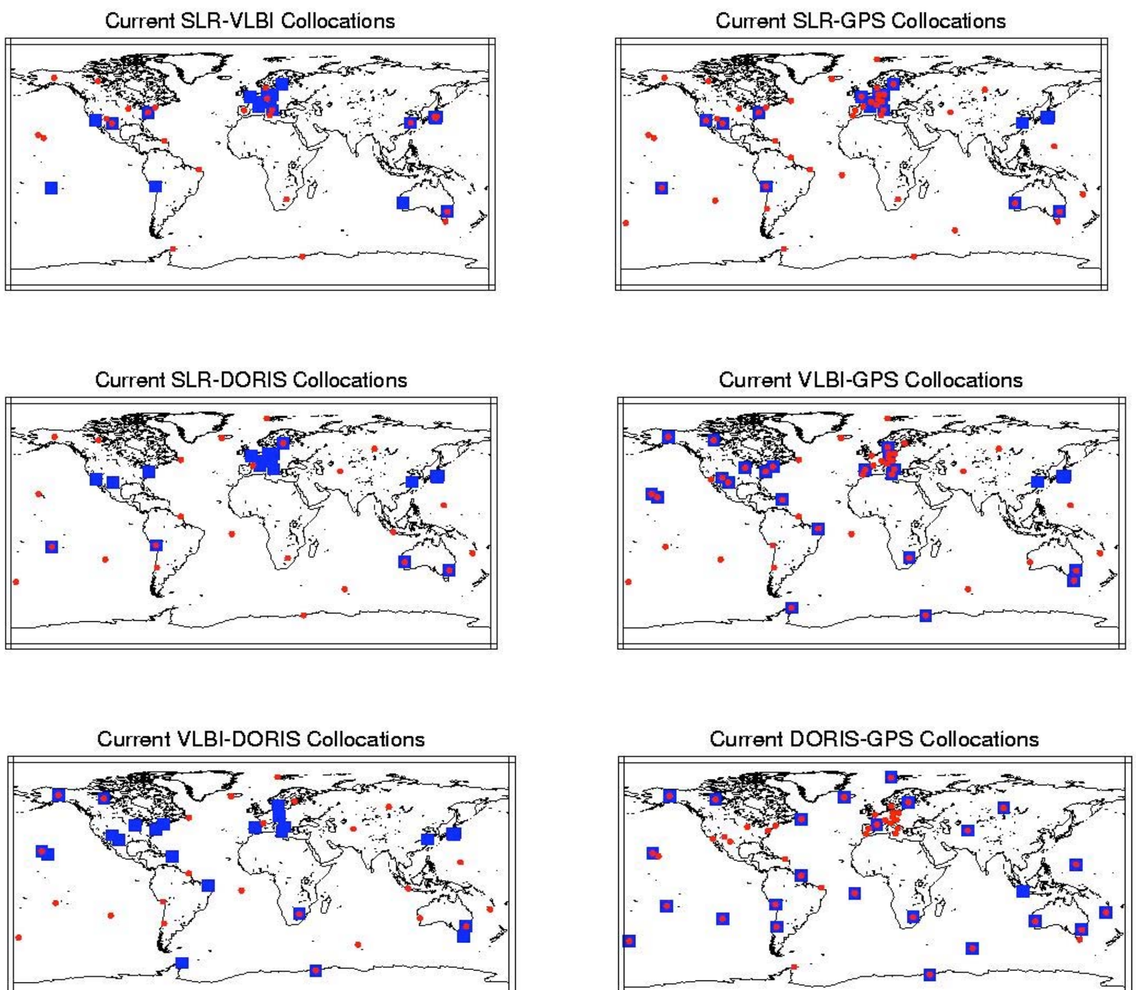

Figure 6. Distribution of the collocation sites by pair of techniques for the year 1999.

To combine the above per-technique solutions, we adopted the following analysis strategy:

- Apply identical minimum constraints to all loosely constrained solutions (all SLR solutions)
- Use the minimally constrained solutions (GPS, VLBI, DORIS) as they are
- Perform per-technique combinations (TRF + EOP), all expressed in ITRF2000 using equations of minimum constraints

- Combine the per-technique combinations adding local ties
- Estimate variance components and iterate as necessary

A result of the 1999 multi-technique combination, Figure 7 depicts the post-fit residuals of polar motion components, their rates and LOD.

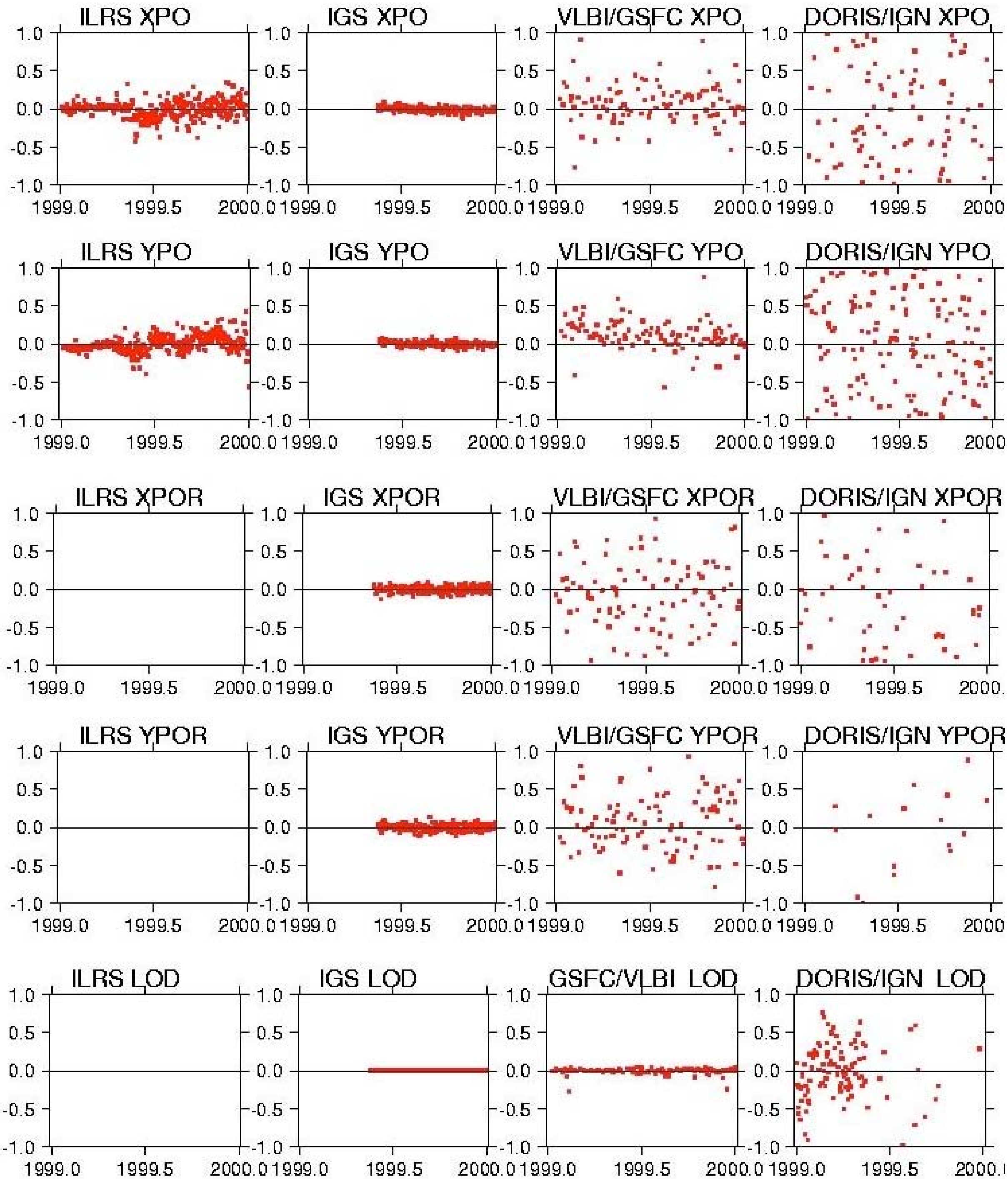

Figure 7. Residuals of polar motion (mas), rates (mas/d) and LOD (ms/d) of the 1999 multi-technique combination.

In addition Figure 8 shows the residuals of one month (April 2001) of a multi-technique combination.

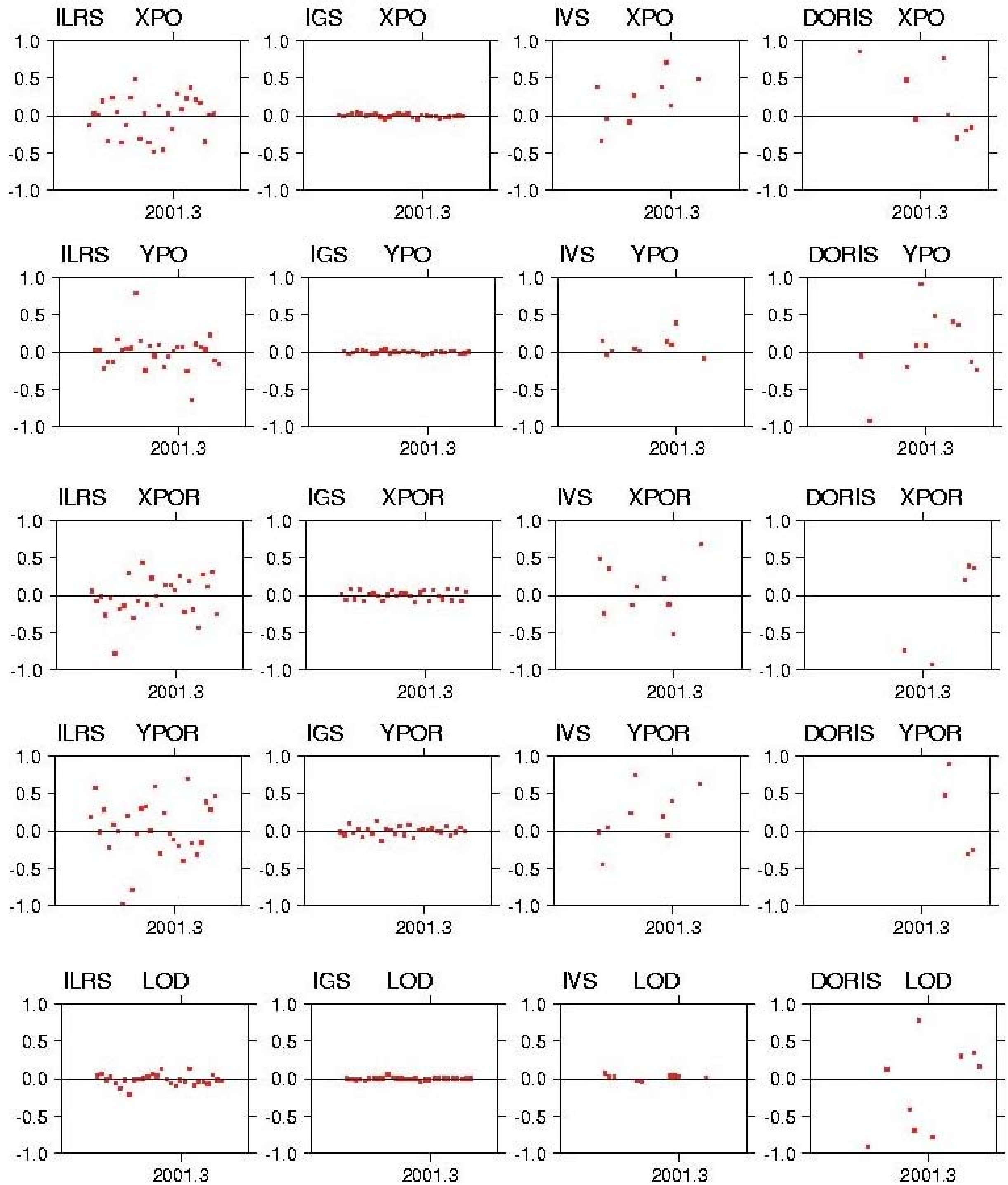

Figure 8. Residuals of polar motion (mas), rates (mas/d) and LOD (ms/d) of the April 2001 multi-technique combination.

Conclusions

The comparison and combination analysis presented in this paper shows that there are small but still existing Tz and scale differences between the ILRS ACs. More refinement is needed for the SLR origin and scale maintenance.

The current SLR and VLBI network and collocation sites are very poor, which impacts the quality of the estimated scale between these two techniques. We see however that there is a good agreement between ILRS ACs estimates of polar motion and LOD. Meanwhile, VLBI and SLR rate estimates of X-pole and Y-pole seem to degrade polar motion estimates of these two techniques. Finally we see that there is a good agreement between the techniques for polar motion and LOD, when the polar motion rates are not estimated.

References

Altamimi, Z., P. Sillard, and C. Boucher, ITRF2000: From Theory to Implementation, V Hotine Marusi symposium, Matera, Italy, 2002.

Altamimi, Z., P. Sillard, and C. Boucher, ITRF2000: A New Release of the International Terrestrial Reference Frame for Earth Science Applications, JGR, 107(B10), 2214, doi:10.1029/2001JB000561, 2002.