Multi-technique Combination of Time Series of Station Positions and Earth Orientation Parameters

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Summary: CATREF software used to generate ITRF solutions was enhanced in order to rigorously combine station positions (and velocities) together with Earth Orientation Parameters (EOP). As a first test analysis, we present in this paper some results of time series combination of TRF and EOP using data provided by various Analysis Centers contributing to the IERS SINEX Combination Campaign. The main focus of this paper is to examine the EOP consistency, through residual analysis, between the main IERS techniques: VLBI, SLR, GPS and DORIS.

1 Introduction

Up to now, the ITRF, ICRF and EOP are determined separately and consequently their consistency is difficult to assess. The IERS SINEX Combination Campaign was organized by the IERS Analysis Coordinator in order to initiate rigorous combination of TRF and EOP targeting improvement and consistency of the IERS products. This paper presents a first tentative to simultaneously combine TRF and EOP which will be extended in the future to include CRF.

2 Combination model

The initial model implemented in CATREF software allows simultaneous combination of station positions and velocities. Assuming that for each individual solution s, and each point i, we have position X_s^i at epoch t_s^i and velocity $\dot{X}_s^i$, expressed in a given TRF k.

- The combination consists in estimating: Positions X_c^i at a given epoch t_0 and velocities $\dot{X}_c^i$, expressed in the combined TRF c
- Transformation parameters T_k at an epoch t_k and their rates $\dot{T}_k$, from the combined TRF c to each individual frame k.

The general combination model is given by the following equation:

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

where for each individual frame k, D_k, T_k and R_k are the scale factor, the translation vector and the rotation matrix, respectively. For more details, see (Altamimi et al., 2002a).

CATREF Software is now upgraded to include Earth Orientation Parameters. Using pole coordinates x_s^p, y_s^p and universal time UT_s as well as their daily time derivatives $\dot{x}_s^p$, $\dot{y}_s^p$ and LOD_s, the corresponding equations are :

$$\begin{cases} x_s^p & = & x^p + R2_k \\ y_s^p & = & y^p + R1_k \\ UT_s & = & UT - \frac{1}{f} R3_k \\ \dot{x}_s^p & = & \dot{x}^p + \dot{R}2_k \\ \dot{y}_s^p & = & \dot{y}^p + \dot{R}1_k \\ LOD_s & = & LOD + \frac{\Lambda_0}{f} \dot{R}3_k \end{cases} \tag{2}$$

where $f = 1.002737909350795$ is the conversion factor from UT to sideral time. Considering $LOD = -\Lambda_0 \frac{dUT}{dt}$, Λ_0 is homogenous to time difference, so that Λ_0 = 1 day in time units.

Note that the link between EOP and TRF is ensured through the 3 rotation angles $R1$, $R2$, $R3$, and their time derivatives $\dot{R}1$, $\dot{R}2$, $\dot{R}3$.

In order to precisely define the datum of the combined frame, minimum constraints equations were implemented in CATREF software, allowing to express 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. (2002b).

3 Analysis Test

We used the following data:

- SLR: ILRS Pilot Project Monthly Solutions provided by ASI, CSR, DGFI and JCET analysis centers
- GPS: IGS weekly combined solutions
- VLBI: GSFC and BKG 24h-session SINEX files
- DORIS: IGN/JPL weekly solutions

We adopted the following analysis strategy:

- Apply minimum constraints equally to all loosely constrained solutions (all SLR solutions)
- Use as they are the minimally constrained solutions (GPS, VLBI, DORIS)
- Perform intra-technique combinations (TRF + EOP), all expressed in ITRF2000 using equations of minimum constraints
- Combine the intra-technique combinations adding local ties
- Estimate variance components and iterate as necessary

Figure 1 shows the origin and scale consistency of some ILRS monthly solutions over 1–3 years. Figure 2 illustrates the polar motion post fit residuals of the per technique combinations for the year 1999 and for April 2001. Similarly, Figure 3 illustrates polar motion rates and LOD.

4 Conclusion

Small T_z and scale differences exist between some SLR analysis centers. SLR and VLBI current networks and collocations are very poor which impacts the long term maintenance of TRF scale. VLBI collocations with other techniques are not always the same at weekly or monthly interval. We find good agreement of X-pole, Y-pole and LOD estimates between the different techniques. VLBI and SLR rate estimates of X-pole and Y-pole seem to degrade polar motion estimates of these two techniques.

References

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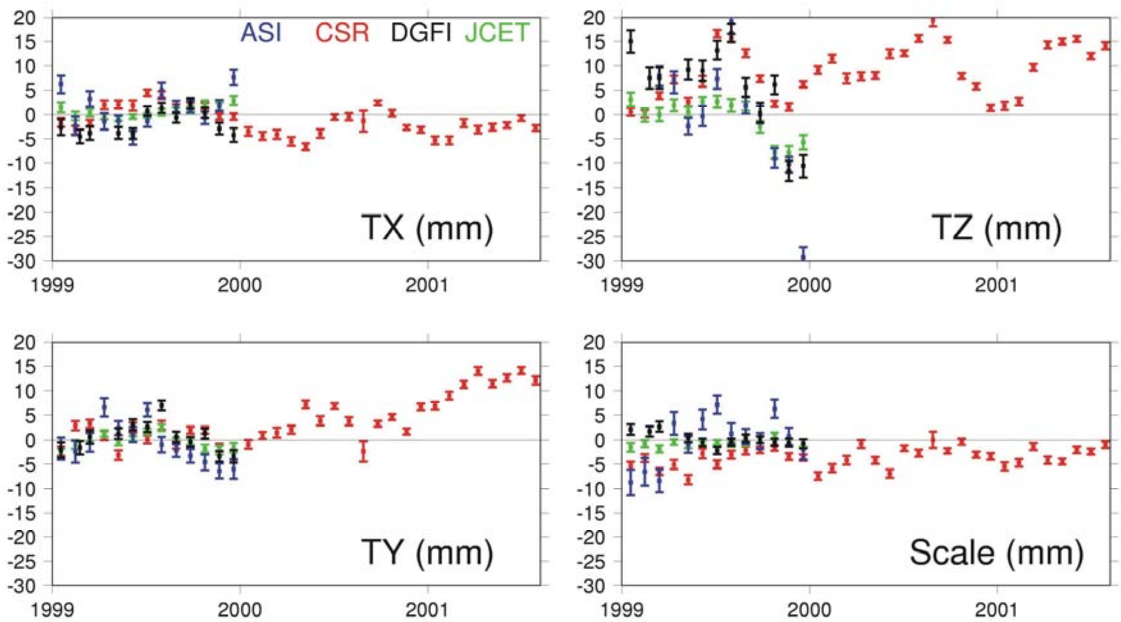

Fig. 1 The origin and scale consistency of some ILRS monthly solutions over 1-3 years

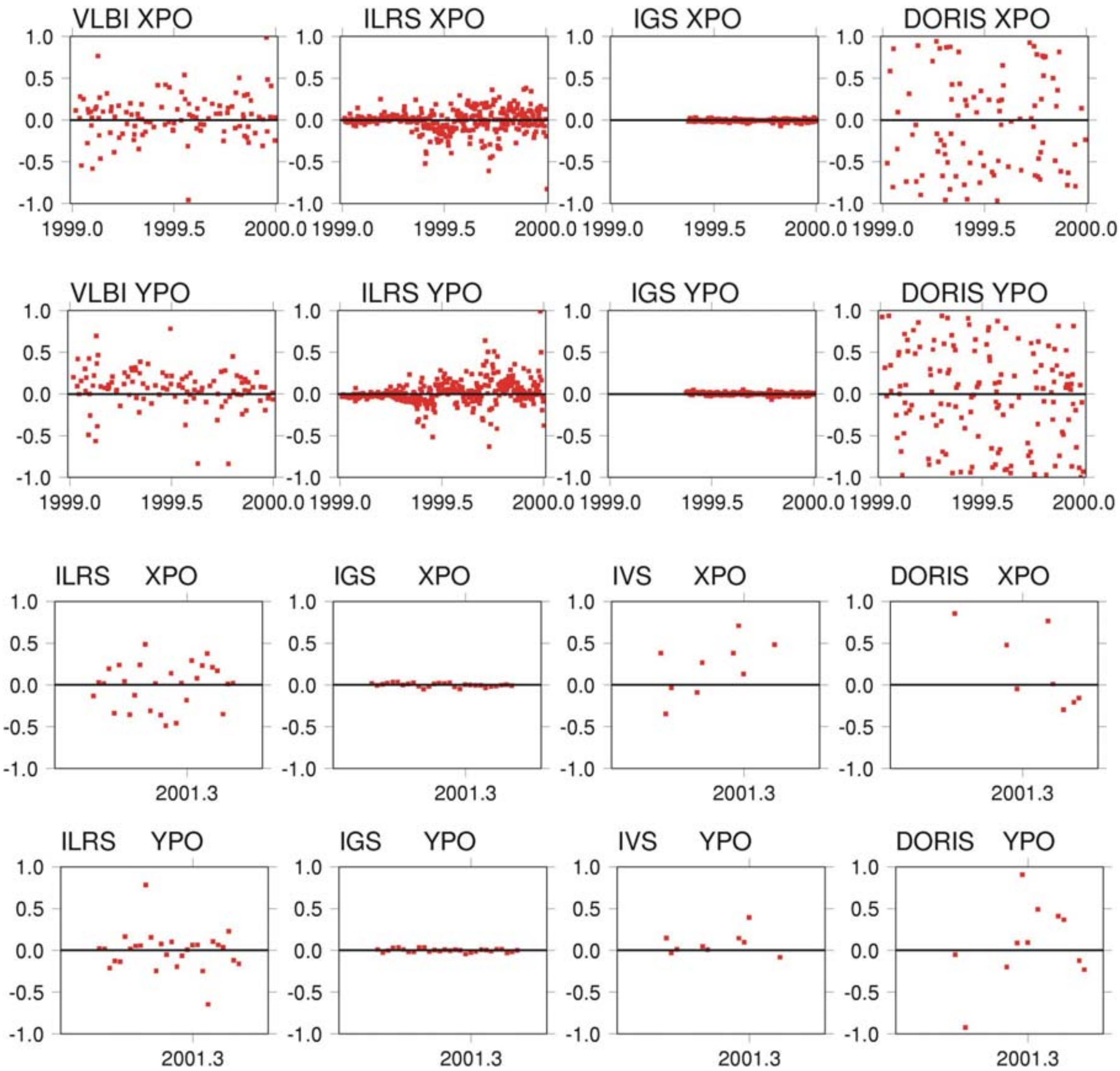

Fig. 2 The polar motion residuals of the per technique combinations for the year 1999 and for April 2001

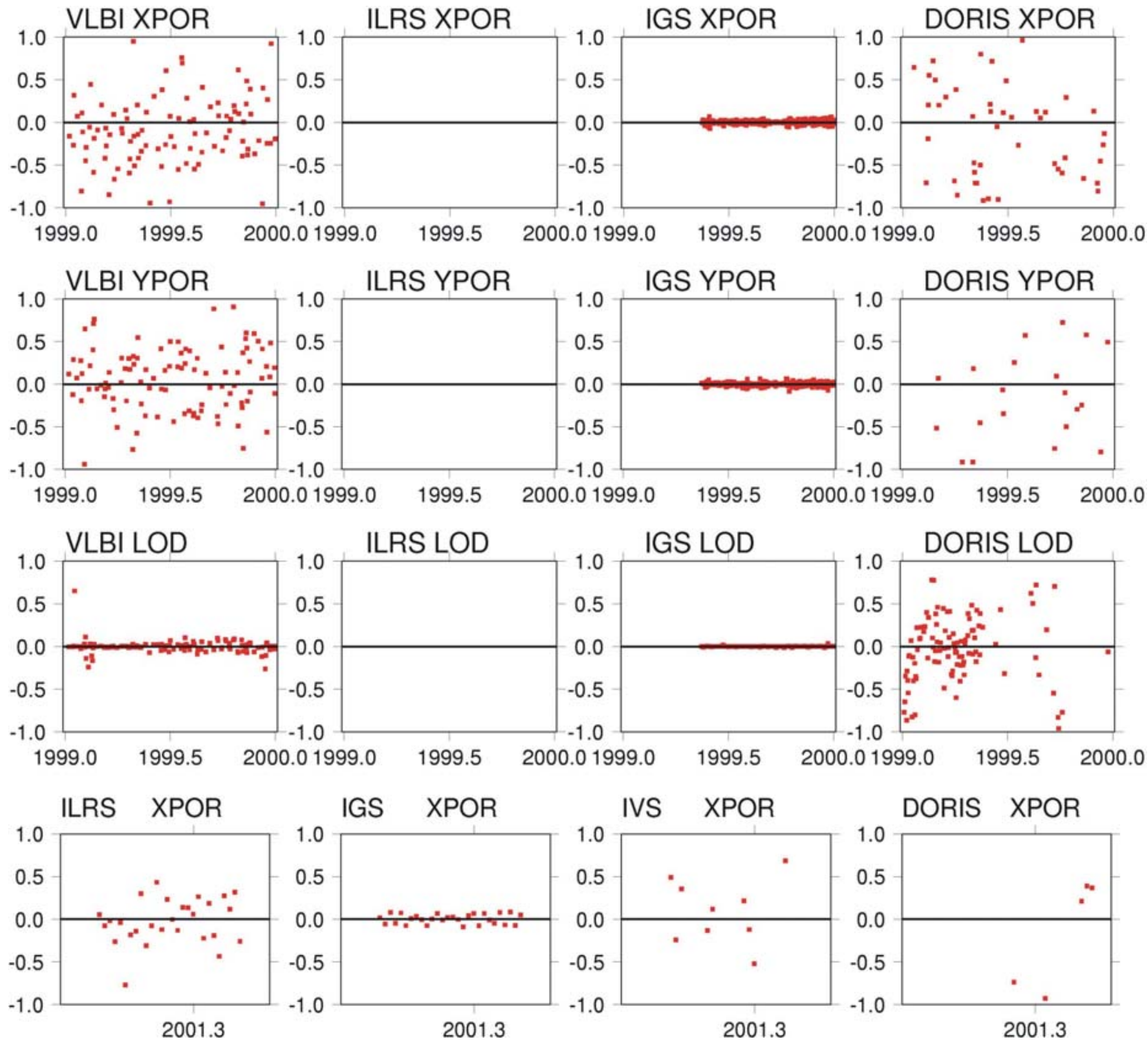

Fig. 3 The polar motion rates and LOD residuals of the per technique combinations for the year 1999 and for April 2001