Tests of IGS Reference Frame Stability

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Abstract

We examine the long-term stability of the IGS internal terrestrial reference frame through times series combination of the IGS weekly combined SINEX solutions. In order to define the combined frame under minimum constraints condition, we used different sets of stations, but still globally distributed, extracted from the IGb00 reference set. Using this approach, we try to assess the behavior and stability over time of the origin, scale and orientation as well as Earth Orientation Parameters, by comparing the different realizations while varying the number and distribution of reference stations.

1. Introduction

Assuming a linear approach of the time evolution of a Terrestrial Reference Frame (TRF), its implementation requires then (1) its definition at a reference epoch, by selection of an origin, a scale and an orientation, and (2) its time evolution by specifying the time derivatives of the origin, scale and orientation. Other definition approaches may require accounting for possible geophysical processes inducing seasonal or short-term variations of local, regional or continental nature. We restrict the study here to the TRF secular part with purely linear time evolution since it represents the current basis of the definition of the International Terrestrial Reference Frame (Altamimi et al. 2002) to which the IGS frame is aligned (Ferland, 2003, Ferland et al. 2004).

To insure full internal consistency, since 2000 the IGS selects a set of reference stations to form the basis of the long-term maintenance of the IGS TRF which is then used in all other IGS products. The "IGS00" frame (currently IGb00 version) is aligned to ITRF2000 through a 14-parameter transformation using a set of high-quality of reference stations (RS), recently increased from 54 to 99, as illustrated in Figure 1. For more discussion on consistency of IGS products and other IGS reference frame issues, see Ray et al (2004).

In this study we try to evaluate the IGS frame behavior over time (or the long-term stability) over the origin, scale, orientation as well as polar motion, when changing the RS from 54 to 99 and when using different sets of reference stations, but still globally distributed.

2. Methodology

We used CATREF software (Altamimi et al. 2003) to combine the IGS weekly combined solutions provided in SINEX files containing station positions and daily Earth Orientation Parameters (EOP), spanning 1999-2003. Our combination consists in using the weekly station positions and daily EOP's as input and estimating mean station positions at a reference epoch (the central epoch of the time series), station velocities and daily EOP's, following the procedure described in (Altamimi, et al. 2002).

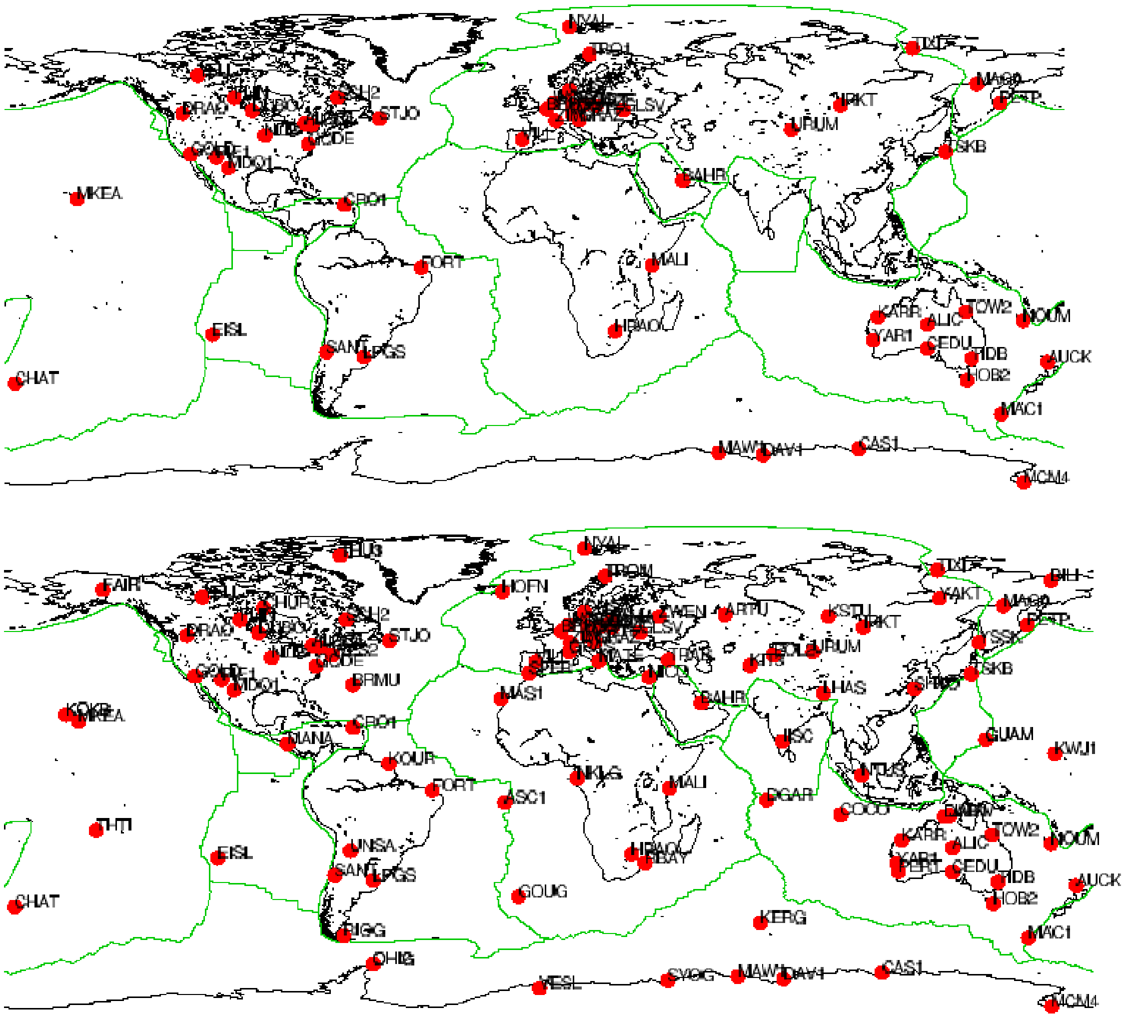

Figure 1. IGS00 Network: 54 stations (Top) and 99 stations (Bottom)

The combined frame resulting from this combination is aligned to the selected subset of reference stations, extracted from the IGb00, using an equation of minimum constraints applied over the frame parameters as

$$(A^T A)^{-1} A^T (X_{RS} - X_c) = 0$$

where $\boldsymbol{X_{RS}}$ is the vector of station positions and velocities of the RS and $\boldsymbol{X_c}$ is the vector of station positions and velocities of the combined frame, and $\boldsymbol{A}$ is the design matrix of partial derivatives given by

$$A = \begin{pmatrix} . & . & . & . & . & . & . \\ 1 & 0 & 0 & x_0^i & 0 & z_0^i & -y_0^i \\ 0 & 1 & 0 & y_0^i & -z_0^i & 0 & x_0^i \\ 0 & 0 & 1 & z_0^i & y_0^i & -x_0^i & 0 \\ . & . & . & . & . & . & . \end{pmatrix}$$

constructed over approximate station positions of the RS.

3. Data Analysis

To study the time behavior of the frame parameters and polar motion as described above, we first performed two combinations of the IGS SINEX files where the combined frame is defined by the 54 stations in the first combination and by the current 99 stations for the second combination. As result from these two combination, Figure 2 illustrates the differences in time variation of the origin components as well as the scale, and Figure 3 shows the differences in polar motion. One should notice that the resulting differences are mainly a shift and a drift over time. Regarding the polar motion differences (Figure 2), they are still within the uncertainties of the considered period, but exceed the uncertainty level beyond that period.

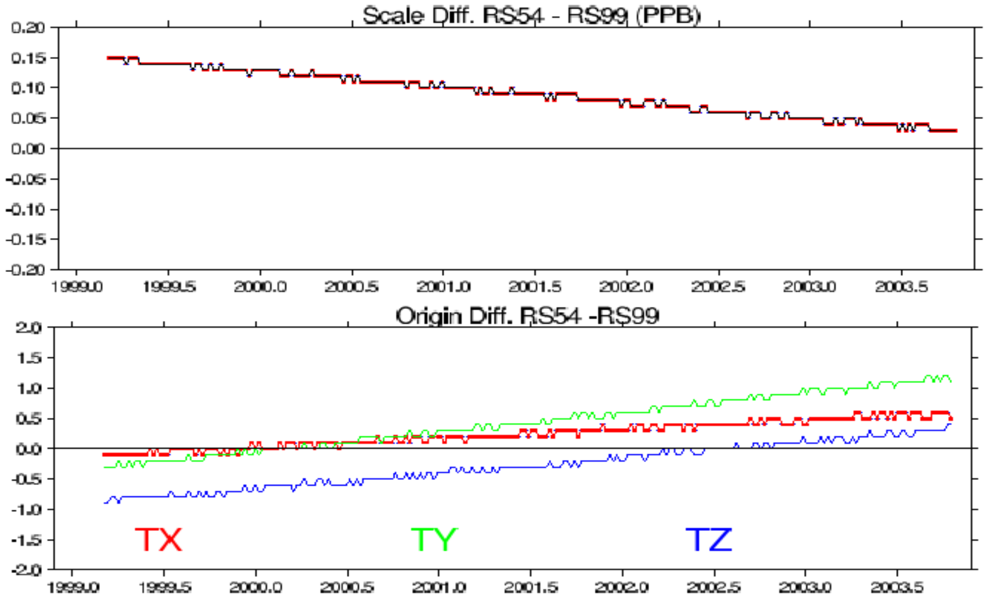

Figure 2. Scale and origin differences in time when changing the reference set from 54 to 99 stations

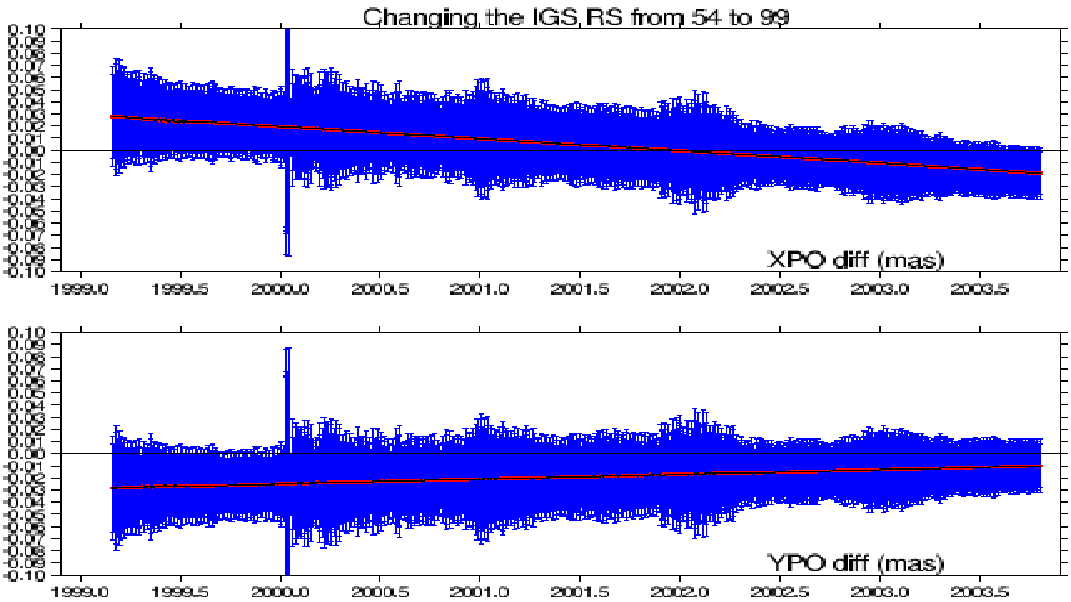

Figure 3. Polar motion differences in time when changing the reference set from 54 to 99 stations

We then performed 10 combinations using different reference sets comprising 25 and 50 stations, but still globally distributed to evaluate the network effect on the frame stability over time. As an example, Figure 4 shows the scale and origin differences between a combination using 50 stations as reference set, compared to the combination with 99 stations, and Figure 5 shows the differences in polar motion.

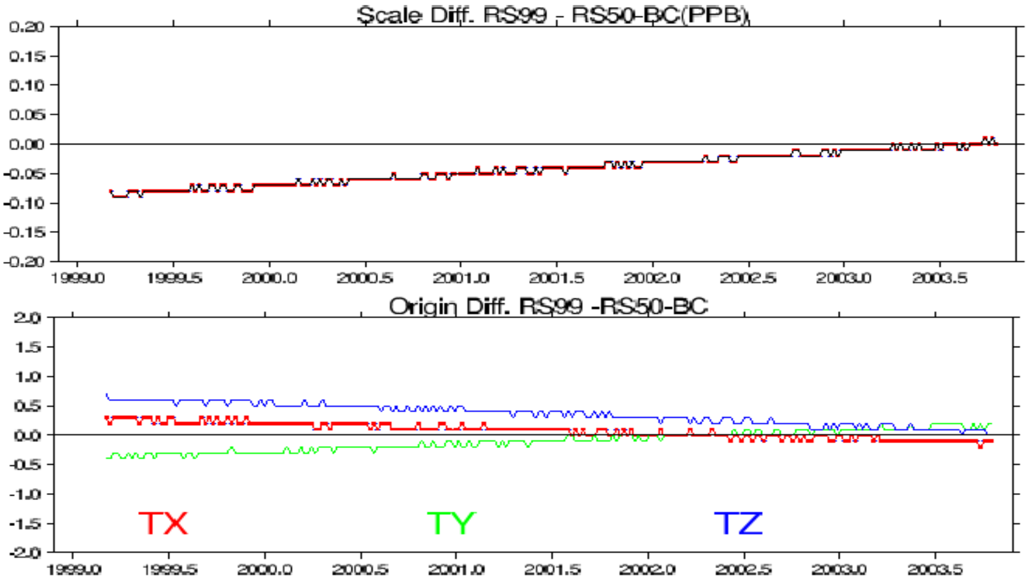

Figure 4. Scale and origin differences in time when using 50 stations as reference compared to a combination using 99 stations

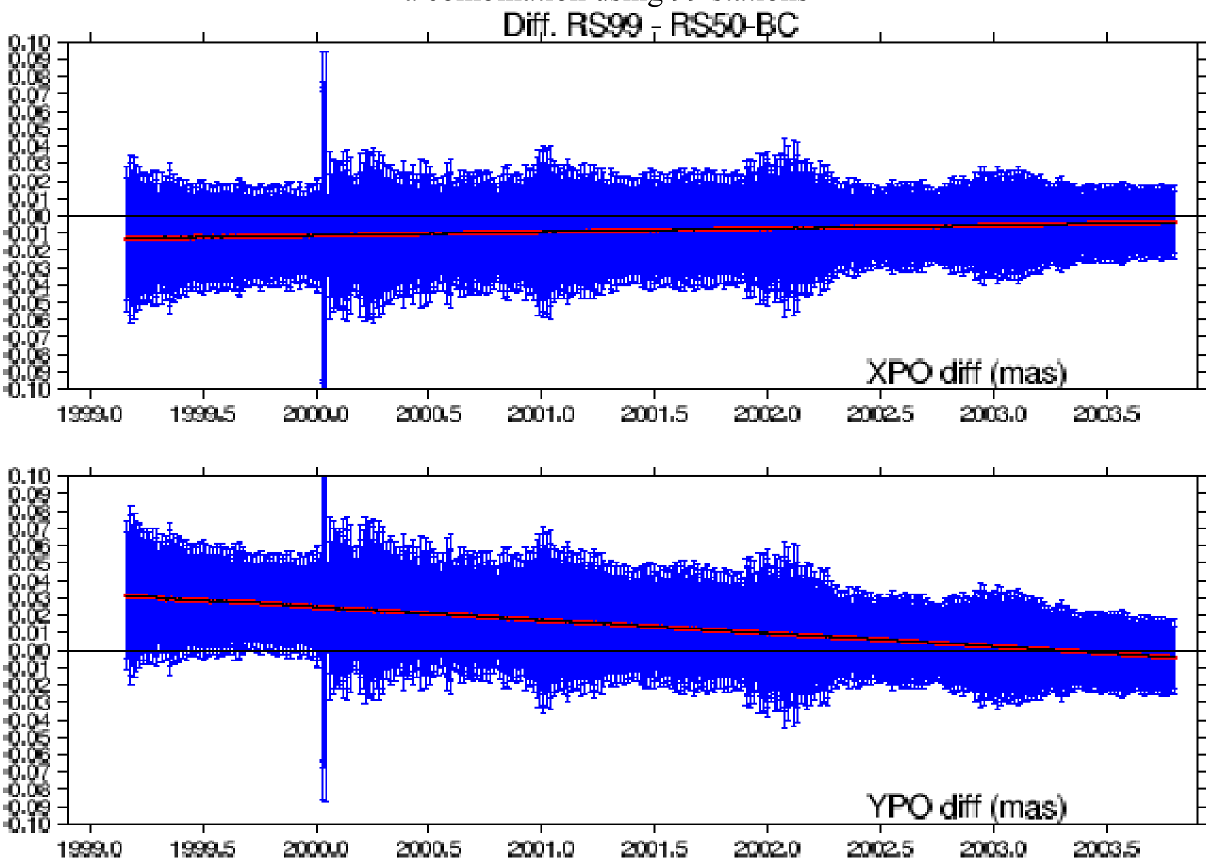

Figure 5. Polar motion differences in time when using 50 stations as reference compared to a combination using 99 stations

Moreover, in order to evaluate the impact of discontinuities in the time series, we performed a combination in which we imposed equal station velocities for Arequipa site before and after the earthquake occurred on day 174 of year 2001. Figure 6 shows the impact on polar motion, exactly at the earthquake day and after; a rupture of 40 micro-arc-seconds is visible.

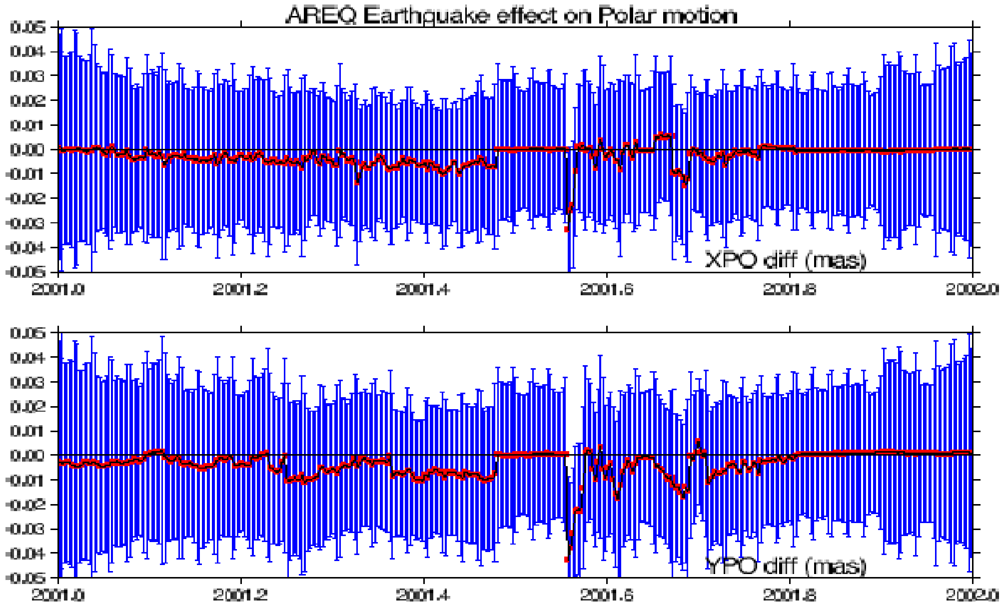

Figure 6. Impact of AREQ Earthquake on Polar Motion if pre & post station velocity is constrained to be the same

Finally, the procedure adopted for time series combination allow us to evaluate the quality of the TRF in terms of repeatability, that is by computing the weekly WRMS over station position residuals. Figure 7 plots the computed WRMS per week as results from the combination using the 99 stations as reference set.

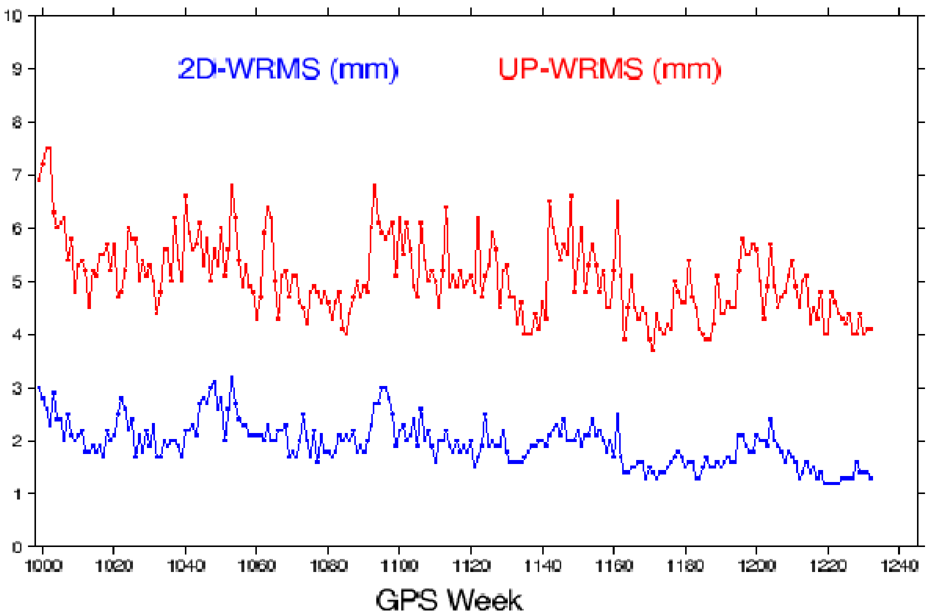

Figure 7 Weekly WRMS computed over station position residuals

4. Conclusion

Ideally, to accurately maintain the stability of the IGS terrestrial reference frame over time, a unique well distributed set of reference stations is desirable. But this is hardly achievable to maintain exactly the same number of the RS, for many operational and technical reasons. Therefore it is advisable to have as many reference stations as possible (but globally distributed) in order to minimize the impact on the TRF when stations are dropped or no longer operational. However, from the analysis presented in this paper, we can conclude that the overall IGS TRF stability is believed to be at the one mm level, noting that the change of reference set may produce changes up to 0.5 mm/yr in origin and scale and about 10 micro-arc-seconds per year in polar motion. The quality of the IGS weekly SINEX files, in terms of WRMS, is around 2 mm horizontally and 5-6 mm vertically. Special care should be observed for discontinuities in the time series because of their impact on frame parameters as well as on polar motion.

References

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