IMPORTANCE OF LOCAL TIES FOR THE ITRF

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Abstract: The key-element of the construction of the International Terrestrial Reference Frame (ITRF) is the availability of co-location sites where two or more space geodesy instruments are operating and where differential coordinates (local ties) between the measuring reference points of these instruments are determined. The very existence of the ITRF relies on the availability and quality of local ties in co-location sites as well as the number and distribution of these sites over the globe. In this presentation we review the current status of co-location sites of the 4 techniques contributing to the ITRF: VLBI, SLR, GPS and DORIS. After recalling the usage of local ties in the ITRF combination, we will evaluate the impact of their errors on the ITRF quality and reliability as well as on its datum definition and mainly its physical parameters, namely the origin and the scale. Based on the results of the ITRF2005 combination and other analysis, we will isolate co-location site where discrepancies between terrestrial surveys and space geodesy estimates are significant.
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1. INTRODUCTION

When combining TRF solutions of station coordinates provided by different techniques, it is essential to be able to connect these solutions. This could not be possible without having common observing sites of the various techniques. The common sites (collocations) have different instruments and observing monuments for which differential coordinates (local ties) should be available for TRF combination purpose.

Collocation sites represent a key element of the ITRF combination, connecting the individual TRF networks together. Without collocations an inter-technique combined TRF could not exist. A global homogeneous geographical distribution of collocations is desired and the quality of local ties must be high.

2. DEFINITION OF A CO-LOCATION SITE

A collocation site is defined by the fact that two or more space geodesy instruments are occupying or have occupied simultaneously or subsequently close locations which are very precisely surveyed in three dimensions, using classical or GPS surveys. We designate throughout this paper by ``geodetic marker'' or simply ``marker'' an unambiguous, fully defined reference point in space for which we estimate (refer) geodetic coordinates. The marker could be either:

- a well defined physical point anchored/settled in a geodetic monument (pillar, pole, etc.), or
- an instrument reference point (e.g. intersection of axes of SLR telescope or VLBI antenna, GPS/DORIS Antenna Reference Point)

There are at least two main criteria which could be considered for the definition of a collocation site:

- **Inter-marker distance**: typical distance between geodetic markers in a collocation site is of the order of few hundred meters. One could impose a given ``maximum'' length of distance between markers for an ideal collocation site. Meanwhile the current reality of the available collocation sites (insufficient number and distribution) lead to consider distances up to 30 km (e.g. Tidbinbilla/Orroral complex site). Moreover, footprint network and repeated survey should be established for local site long-term stability. In any case the accuracy of the local tie should be properly taken into account in TRF combination.
- **Accuracy of the local tie**: the typical uncertainty when available of the currently available local ties for ITRF combination ranges between 1 to 3 mm (sometimes larger than 3 mm for imprecise ties). Note that within a collocation site, several geodetic markers per technique are often present. Therefore the accuracy of local ties between pair of markers may vary from one vector to another depending on the quality of the available survey.}. Given the precision increase of the measurement of the space geodesy techniques and modelling, 1 mm precision or better should be the goal of all new local tie surveys. Moreover, SINEX files with full variance-covariance information is now mandatory.

3. LOCAL TIE USAGE IN ITRF COMBINATION

The usual procedure adopted for the ITRF combination is to use the local ties as independent measurements with proper weighting. Taking the ITRF2005 (Altamimi et al. 2007) as an example, about 45% of the available local ties are provided in SINEX files with full variance-covariance information as well as the measurement epochs. All the local tie SINEX files used in the ITRF2005 combination are available at http://itrf.ensg.ign.fr/local_surveys.php.

The local tie SINEX files were introduced in the ITRF2005 combination as independent solutions, in the same way as the long-term space geodesy solutions. Empirical variance factor estimation for each one of the individual local tie solutions (SINEX files) is operated following the procedure described in (Altamimi et al. 2002), Appendix A, section A5. The global combination is iterated as necessary and new variance factors are estimated at each run and in such a way that any position component should not exhibit a residual exceeding a certain chosen threshold. For the ITRF2005 solution it was decided to avoid having a position or velocity normalized residual (raw residual divided by its observation a priori error) exceeding a threshold of 4. Note that in each iteration, new individual variance factors are estimated which are then used to re-scale the individual matrices for the next iteration. A list of local tie vectors, together with their uncertainties as extracted from the re-scaled SINEX files, is also available at the same place as the SINEX files as mentioned above.

In addition, all the post-fit residuals of the ITRF2005 combination are available at the ITRF2005 web site. These residuals reflect, site by site, the level of agreement between the local ties and space geodesy estimates. There are some important co-located sites where we observe discrepancies larger than or equal to 1 cm, between local ties and space geodesy estimates. These discrepancies mean that either local ties or space geodesy estimates (or both) are imprecise or in error. Example of such sites are: GPS/VLBI: Westford, USA and Fortaleza, Brazil; GPS/SLR: Zimmerwald, Switzerland and Herstmonceux, UK. In order to preserve the implied co-locations in the combination, the local ties having normalized residuals exceeding the threshold of 4 were down-weighted rather than rejected, through the usage of appropriate variance factor as mentioned above.

4. QUALITY EVALUATION OF AVAILABLE LOCAL TIES

In order to evaluate the quality and the impact of local ties in the ITRF combinations, we selected here the most pertinent sites connecting GPS, SLR and VLBI co-located stations. Using the local ties of these co-located stations, we elaborated an ITRF2005-like combination and computed the Weighted Root Mean Scatter of the tie residuals in East, North and Up components. This test combination involves 22 GPS-SLR and 29 GPS-VLBI tie vectors. Note that GPS networks enforce the connection between VLBI and SLR, given the fact that there are 7 usable VLBI-SLR co-locations only, a very small number to allow reliable connection between these two techniques. As results of this test combination, Figure 1 illustrates the tie residuals over the 51 involved sites, indicating that the tie quality (in terms of WRMS) is at the level of 3-5 mm.

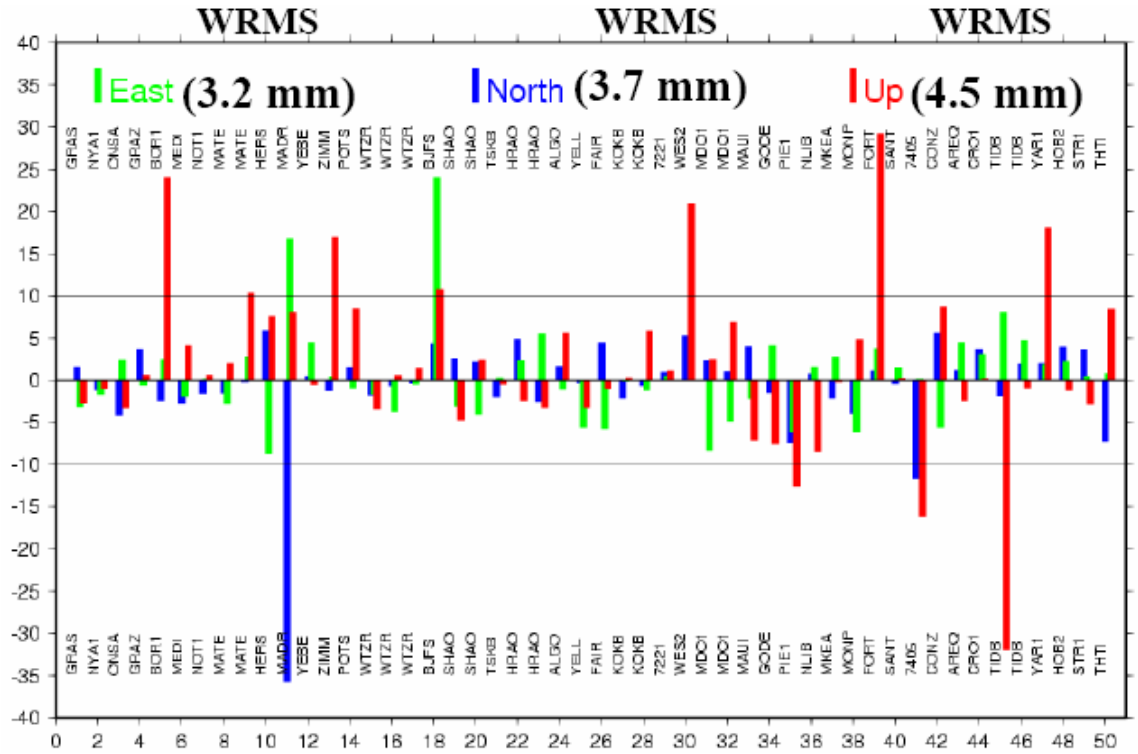

Figure 1 - Local tie residuals as results of an ITRF-like combination

5. DISCUSSION AND CONCLUSION

The key-element of the ITRF combinations is the availability of co-location sites where local ties between the measuring instruments are determined. Distribution and number of co-locations, as well as the quality of local ties are a major quality measure of the ITRF combinations. Unfortunately, the currently available co-locations, their distribution and number and the quality of local ties are far from optimal. However the impact of local ties in the ITRF combinations is mitigated by an appropriate weighting and so the quality of local ties available at the ITRF product center is evaluated to be at the level of 3-5 mm. Improvement of the quality of local ties as well as the number of co-locations need an international contribution of space agencies and country operating these sites. Among the most important points of weakness to be improved, we can mention the following:

- Poor distribution of VLBI and SLR networks and their co-locations
- Discontinuities in the GPS time series due to equipment changes, and in co-location sites, this is a limiting factor about the reliability of local ties.
- There are all in all 50 useable co-location sites and their distribution is far from optimal.

Finally, we believe that the ultimate accuracy of local ties needed to derive robust ITRF combination is at the 1 mm level. Whether this is possible nowadays or not, the question needs to be debated with all the field experts from FIG and IAG.

References

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