3.6 Combination Centres
3.6.1 ITRS Combination Centres
3.6.1.1 Deutsches Geodätisches Forschungsinstitut (DGFI)

The work of the ITRS Combination Centre at DGFI concentrated in 2007 on analyses of the ITRF computations and comparisons of the different strategies. Another focus was on the handling of non-linear station motions, which is an important issue for future ITRF realizations.

Introduction and overview

The ITRF2005 was officially released by the ITRS Centre in October 2006. At the end of 2006 the ITRF2005 results were analysed and comparisons between the IGN and DGFI solutions were performed (see IERS Annual Report 2006, section 3.6.1.1). A major outcome of the analysis and comparisons was that there is a good agreement between the ITRF2005 solutions of IGN and DGFI after appling similarity transformations. Most of the similarity transformation parameters are small within their standard deviations, except for the scale and its time variation of the SLR network. A significant difference of nearly 1 ppb (offset at the reference epoch 2000.0) and 0.13 ppb/yr (rate) between the DGFI and IGN solutions has been found, which accumulates to nearly 2 ppb at the end of 2007. This scale discrepancy was extensively discussed within the IERS and the Techniqes' Services, in particular with the ILRS. As a consequence of the fact, that SLR observations are not consistent with the ITRF2005, it was decided by IGN to provide a second (re-scaled) ITRF2005 for SLR users. Taking into account this situation, it was necessary to perform further investigations on the ITRF computation strategies. It was agreed by IGN and DGFI to identify the differerences in the computation strategies between both ITRS Combination Centres and to perform further test computations to assess the effect of the differences on the combination results.

Comparison of IGN and DGFI combination strategies

The computation strategy of IGN is based on the solution level by simultaneously estimating similarity transformation parameters w.r.t. the combined frame along with the adjustment of station positions, velocities and EOPs. The general concept of DGFI is the combination of normal equations and the common adjustment of station positions, velocities and EOP. A comparison of the combination strategies of both ITRS Combination Centers is provided in Tab. 1.

A major difference is that IGN is estimating similarity transformation parameters between epoch solutions as well as between per-technique solutions and the combined frame. DGFI accumulates normal equations without estimating similarity transformations. The estimation of similarity transformation parameters has some prob-

Table 1: Comparison of the combination strategies of IGN and DGFI

	IGN	**DGFI**
Software	CATREF	DOGS-CS
Time series combination	Stacking of minimum constrained solutions, 7 transformation param.	Accumulation of normal equations, without transformations
Inter-technique combination	Combination of per-technique solutions, 14 transformation param. IGN selected set of local ties	Accumulation of per-technique normal equations, without transform. DGFI selected set of local ties
ITRF2005 datum – Origin – Scale – Rotation – Rotation rate	 SLR VLBI 3 NNR conditions w.r.t. ITRF2000 3 NNR conditions w.r.t. NUVEL-1A	 SLR VLBI + SLR (weighted mean) 3 NNR conditions w.r.t. ITRF2000 3 NNR conditions w.r.t. APKIM2005

lems: (1) terrestrial networks in different epochs are not geometrically similar at the accuracy-level of the station coordinates (mm) due to irregular (crustal) deformations; (2) if the entire reference frame (station network) is moving with respect to the given datum, a similarity transformation from the new to the old positions by parameter estimation changes the datum and thus violates the definition of the reference system; (3) all common motions of the stations of the reference network are transformed into the similarity parameters (shift of origin, change of orientation, scale factor). According to the ITRS definition, the datum parameters of the terrestrial reference system shall be fixed in the geocenter, and coordinate changes caused by the station movements must go to the individual station coordinates and not to the datum.

Effect of co-location sites and handling of local ties

The selection and the weighting of local tie information is a critical issue for the combination of different space techniques, since the distribution of “good” co-location sites is relatively sparse (see Fig. 1). A “good” co-location site means, that the differences between the local tie measurements and the space geodetic solutions are relatively small (below 15 mm).

Co-location sites between SLR and GPS

The geographical distribution of SLR tracking stations is in particular problematic in the southern hemisphere. There are 8 co-location sites between SLR and GPS. Fig. 2 shows the observation statistics of these sites. Among them are two stations with very few SLR data (Easter Island and Conception), and Arequipa, which has been affected by post-seismic deformation after the earthquakes in June, 2001. Tab. 2 shows the different sets of co-location sites used by IGN and DGFI.

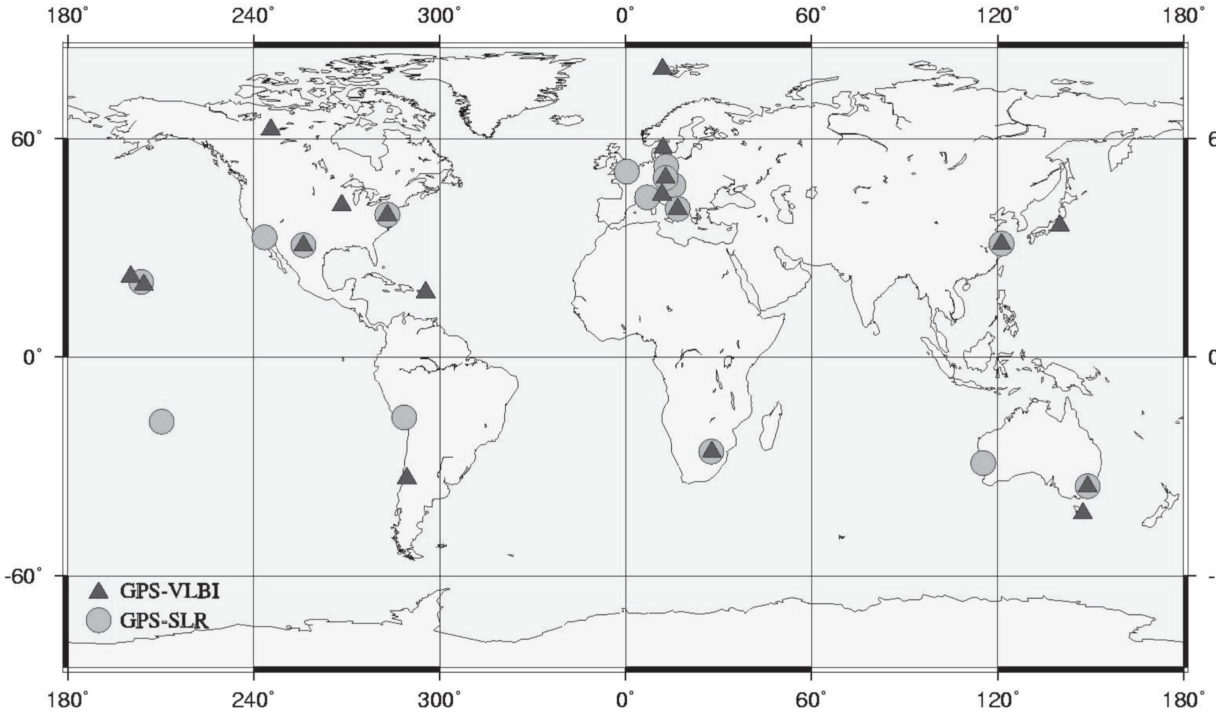

Fig. 1: Distribution of "good" co-location sites between GPS, SLR and VLBI

We investigated the effect of a different local tie selection on the combination results by means of similarity transformations. We performed two solutions with different sets of co-location sites. As shown in Tab. 3 there is an impact of almost 1 ppb on the scale difference between SLR and VLBI, if different sets of local ties are selected. However, taking into account the standard deviations for the scale offsets and time derivatives, the observed differences are not significant. Furthermore, the results depend on the similarity transformations.

Table 2: SLR and GPS co-location sites in the southern hemisphere.

Site name	**DGFI**	**IGN**
Harthebeesthoek	Used	Used
Easter Island	Not used	Used
Arequipa	Used	Used
Conception	Not used	Used
Mt. Stromlo	Used	Down-weighted
Orroral / Tidbinbilla	Used	Down-weighted
Yaragadee	Used	Down-weighted
Tahiti / Pamatai	Used	Down-weighted

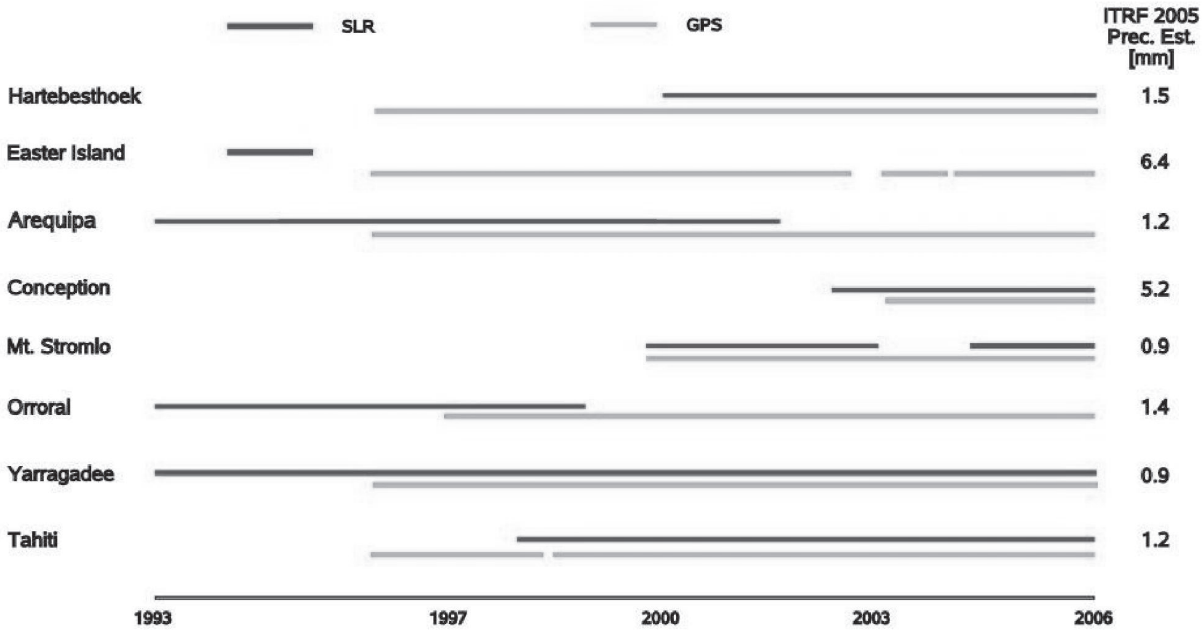

Fig. 2: Observation periods for SLR and GPS co-location sites in the southern hemisphere.

Handling of non-linear station motions

From the time series analysis of the ITRF2005 data it was found, that for most of the stations seasonal signals with amplitudes up to 2 cm are visible, especially in the height component (see Fig. 3 as an example). These seasonal signals may be caused by atmospheric and hydrological loading effects, which are presently not reduced from the original observations. In other cases, also instrumentation effects (rather than geophysical ones) may be responsible for the observed signals.

Deficiencies regarding the current reference frame computations are that the temporal variations of station positions are described only by constant velocities. Deviations of the station motions from a linear model (e.g., seasonal variations) will produce errors in the combination results. In particular for stations with relatively short observation time spans (i.e., < 2 years) seasonal variations will

Table 3: Scale differences between SLR and VLBI observations obtained from two solutions. Solution 1 refers to the local tie selection used by DGFI, and solution 2 to the IGN selection (see Tab. 2).

Solution type	Δ Scale offset [ppb]	Δ Scale rate [ppb/yr]
Solution 1	0.26 ± 0.41	0.03 ± 0.09
Solution 2	1.05 ± 0.44	0.11 ± 0.10

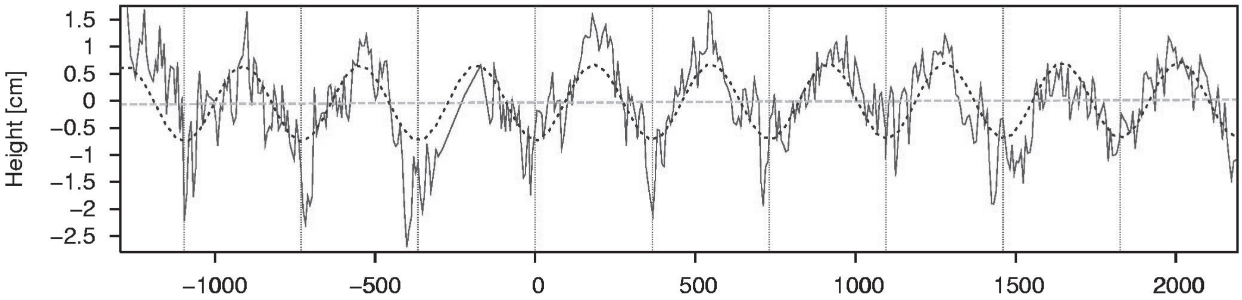

Fig. 3: Seasonal variations for the height component for the GPS station in Irkutsk, Siberia. The time is given in Julian Days (w.r.t. 1.1.2000) from 1996.5 until the end of 2005.

affect the velocity estimations. The alignment of epoch solutions to a reference frame with positions and constant velocities is also affected by non-linear station motions. The shape of these non-linear motions differs between stations. Fig. 4 shows two examples for the mean average shape of such annual variations.

While the Brasilia time series clearly shows a maximum and a minimum, Ankara has not a clear minimum. The averaged annual motions of both stations can be rather well mathematically represented by sine/cosine annual and semi-annual functions. The computation of a mean (averaged) annual motion is problematic, in particular if the seasonal variations are different over the observation time span. It is also clear, that the additional parameters will affect the stability of the solution, which is in particular a problem for stations with rather short observation time spans. Thus, the handling of seasonal variations in station positions is a challenge for future ITRF computations.

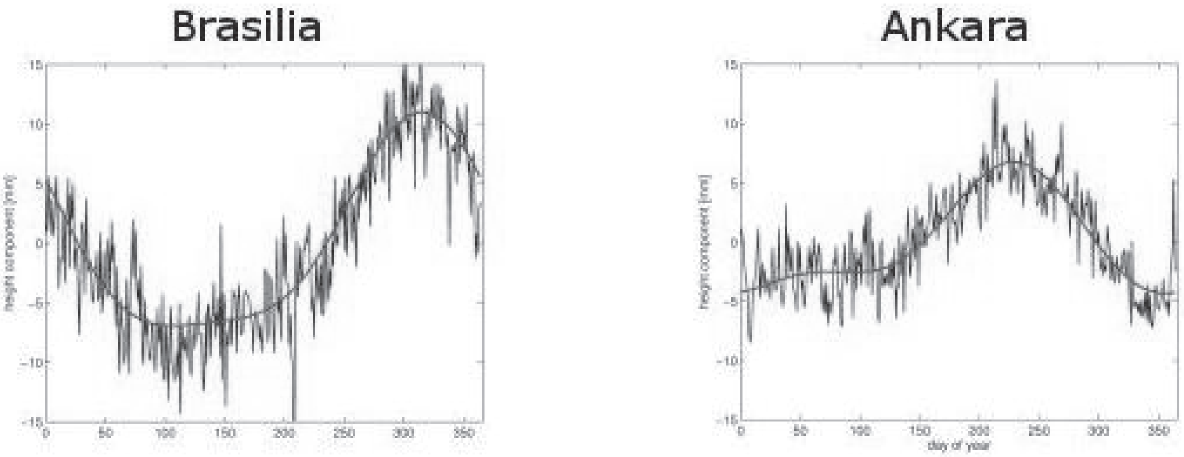

Fig. 4: Shape of the "averaged" annual signal for two ITRF2005 stations. The fitted curve represents the mathematical approximation by annual and semi-annual sine/cosine functions.

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