# 3.6 Combination Centres

## 3.6.1 ITRS Combination Centres

### 3.6.1.1 Deutsches Geodätisches Forschungsinstitut (DGFI)

During the year 2005 the DGFI activities as ITRS Combination Centre concentrated on the ITRF2005 computations, which are based on the combination of epoch normal equations (weekly/session data sets) of station positions and Earth orientation parameters (EOP) from the geodetic space techniques VLBI, SLR, GPS and DORIS. In addition to this report, several publications of the ITRS Combination Centre at DGFI are available (see references).

**Input data for ITRF2005**

Single-technique combined GPS, SLR and VLBI solutions were submitted by the Techniques' Combination Centres, namely the National Resources Canada (NRCan, IGS), the Geodetic Institute of the University Bonn (GIUB, IVS), and the Agenzia Spaziale Italiana (ASI, ILRS). Until now, no combined DORIS solutions are available by the IDS. Two individual solutions of DORIS Analysis Centres (IGN/JPL, LCA) are provided for the ITRF2005. In addition to the SINEX solutions the Technique Centres also provided a list with information about discontinuities (e.g. equipment changes, earthquakes) in station positions, which are used as input by the ITRS Combination Centres. Furthermore an updated version of local tie information was provided by the ITRS Centre.

*Tab. 1: Input data sets for ITRF2005*

| Technique | Service / AC | Data | Time period | Parameters | Constraints |
|---|---|---|---|---|---|
| GPS | IGS<br>NRCan | Weekly solutions | 1996–2005<br>from June 1999<br>from March 1999 | Station positions<br>EOP (pole + rates, LOD)<br>Geocentre | NNT: 0.1 mm<br>NNR: 0.3 mm<br>NNS: 0.02 ppb |
| VLBI | IVS<br>GIUB | Daily sessions' free NEQs | 1984–2005 | Station positions<br>EOP (pole, UT1 + rates) | None<br>None |
| SLR | ILRS<br>ASI | Weekly solutions | 1993–2005 | Station positions<br>EOP (pole + LOD) | 1 m<br>1 m |
| DORIS | IGN/JPL<br><br>LCA | Weekly sol.<br><br>Weekly sol. | 1993–2005<br><br>1993–2005 | Station positions<br>EOP (pole, UT1 + rates)<br>Station positions<br>EOP (pole) | Loose<br><br>Loose |

**Combination methodology**

The general concept of the ITRS Combination Centre at DGFI is based on the combination of normal equations and the common adjustment of station positions, velocities and EOP using the DGFI Orbit and Geodetic Parameter Estimation Software (DOGS). The processing procedure for the ITRF2005 computation is shown in Figure 1.

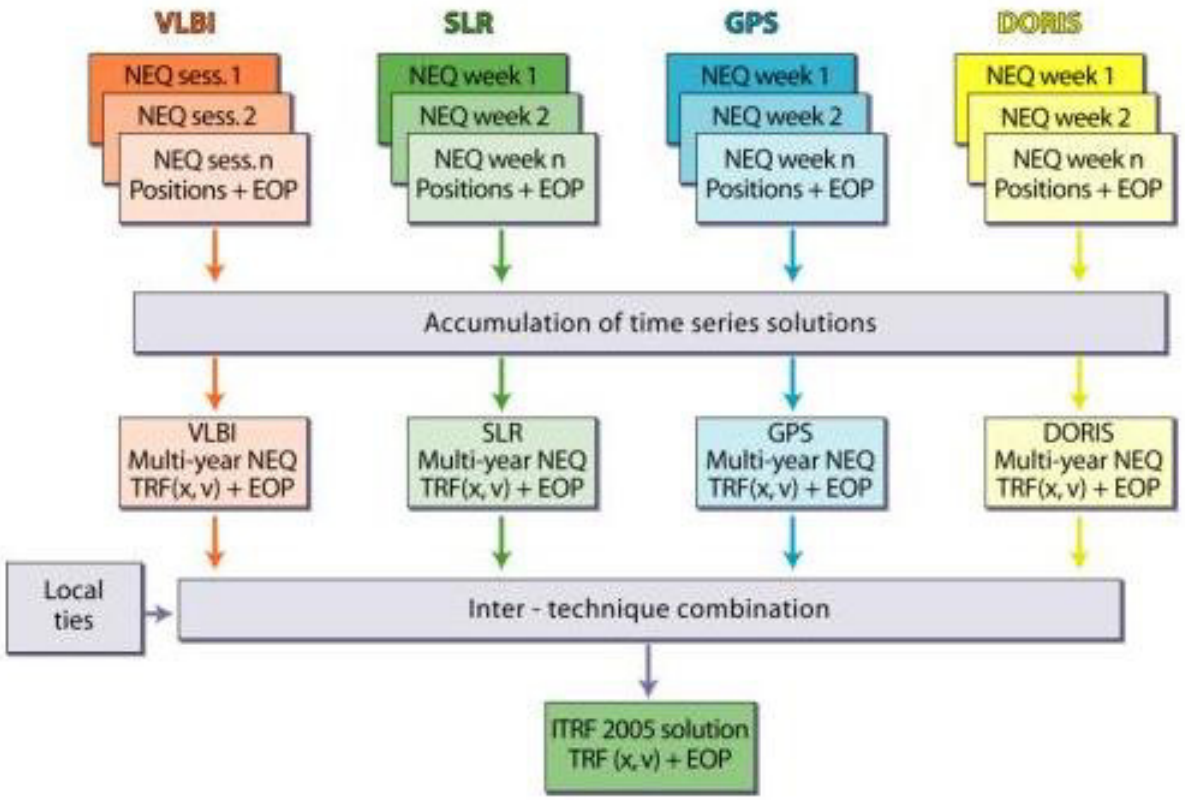


*Fig. 1: Processing procedure for ITRF2005*

## Accumulation of time series solutions

For each technique the epoch normal equations were accumulated separately to compute multi-year solutions with station positions, velocities and EOP. In the case of discontinuities (provided by the Technique Centres) new position and velocity parameters for the corresponding station were introduced. Epoch solutions were computed by applying minimum datum constraints w.r.t. the multi-year solutions. The resulting time series of station positions and datum parameters were analysed in detail. Figure 2 as an example shows the time series for the station heights of the GPS station Irkutsk (Siberia) with a significant annual signal. Especially in short time intervals (e.g. less than 2.5 years) annual signals may affect the linear approach with station positions and velocities (see Table 2).

*Tab 2: Station height velocity differences between a linear model and the estimation of additional annual signals for GPS station IRKT.*

| Data time span [yrs] | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 4.0 | 7.0 |
|---|---|---|---|---|---|---|---|---|
| Δ velocities [mm/yr] | –37.5 ± 3.2 | –3.7 ± 2.3 | 0.1 ± 1.0 | 2.7 ± 0.8 | 1.0 ± 0.6 | –0.1 ± 0.5 | –0.5 ± 0.3 | 0.03 ± 0.1 |

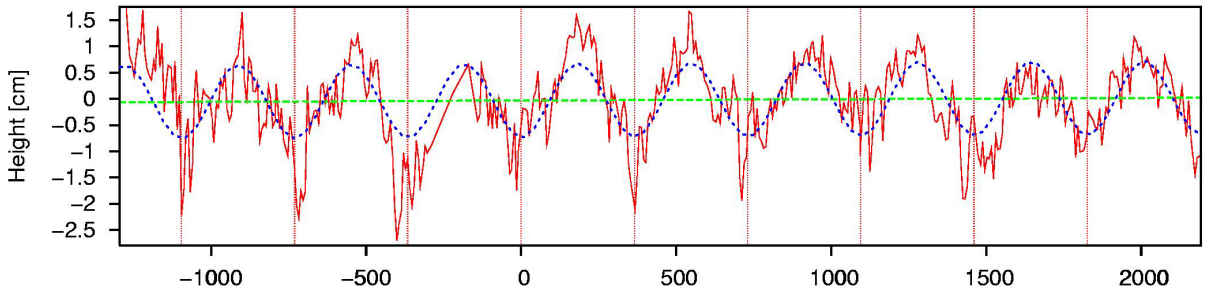


*Fig. 2: Time series for the station heights of GPS station IRKT (Irkutsk, Siberia)*

The repeatabilities of the weekly (daily) position estimates provide valuable information to assess the internal accuracy of the space geodetic solutions. The results obtained for the different space techniques are summarized in Table 3.

*Tab. 3: Repeatability of station position estimates for different space techniques. Note, that in the case of VLBI daily sessions were used, whereas the other technique solutions are weekly.*

| Technique | TC / AC | North [cm] | East [cm] | Up [cm] |
|---|---|---|---|---|
| GPS | IGS | 0.22 | 0.26 | 0.64 |
| VLBI | IVS | 0.53 | 0.52 | 1.5 |
| SLR | ILRS | 1.2 | 1.2 | 1.3 |
| DORIS | IGN/JPL | 2.7 | 3.7 | 2.5 |

The status of the computations at the end of the year 2005 was the following: The intra-technique combinations were almost finalized for GPS; only a few weekly solutions until 2006.0 had to be added in early 2006. The intra-technique combinations for VLBI and SLR were preliminary as new input data had to be submitted in the beginning of 2006. As the IDS does not provide combined DORIS solutions as input for ITRF2005, the DORIS intra-technique combination has to be performed by the ITRS Combination Centres.

## Inter-technique combination

Input for the combination are the accumulated intra-technique normal equations of VLBI, SLR, GPS and DORIS solutions. The parameters comprise station positions, velocities and daily EOP. Concerning the combination of EOP of the different space techniques it has to be considered, that the VLBI estimates are referred to the midpoint of a daily VLBI session (from 17 hr to 17 hr), whereas the EOP values of the other techniques are referred to 12 h. Thus, the VLBI EOP estimates have to be transformed to the reference epochs of the other techniques. A key issue within the inter-technique combination is the implementation of local tie information. For this

purpose the EOP are essential to validate the local tie selection and to stabilize the inter-technique combination as additional „global ties“. Other issues include the equating of station velocities of co-located instruments and the weighting between different techniques. In 2005 specific investigations concerning the inter-technique combination were performed and refined methods have been developed, which will be applied for the computation of the ITRF2005 solution as soon as the intra-technique combinations are finalized.

## Comparison among ITRS Combination Centres

The new IERS structure with three ITRS Combination Centres (IGN, NRCan and DGFI) provides an optimal basis for the accuracy evaluation of the terrestrial reference frame computations. For first comparisons among the ITRS Combination Centres results of the GPS intra-technique combination were used, which were based on different strategies (e.g. at DGFI and NRCan velocities of different solutions for a station were not equated, IGN equated most of the velocities). We used for the comparisons a subset of about 65 IGS reference frame stations without discontinuities to estimate RMS differences for station positions and velocities between the different GPS solutions. As shown in Table 4 the results of the three ITRS Combination Centres are in a good agreement.

*Tab. 4: RMS differences for station positions and velocities.*

| ITRS Combination Centres | RMS position differences [mm] | | | RMS velocity differences [mm] | | |
|---|---|---|---|---|---|---|
| | North | East | Up | North | East | Up |
| DGFI – IGN | 0.70 | 0.62 | 1.89 | 0.34 | 0.32 | 0.56 |
| DGFI – NRCan | 0.89 | 0.84 | 1.22 | 0.39 | 0.38 | 0.46 |
| IGN – NRCan | 0.91 | 0.83 | 1.56 | 0.38 | 0.42 | 0.54 |

## Kinematic reference frame

The reference for the station velocities in the ITRF2005 will be given by an actual plate kinematic and crustal deformation model (APKIM) derived from the geodetically observed station coordinate variations. A preliminary model (APKIM2004P) was computed from the preliminary ITRF2005 input data (status end of 2005). It comprises 17 rigid plates of the geophysical PB2002 model and 4 deformation zones (Alps, Persia-Tibet-Burma, Gorda-California, and Andes). The rotation velocities of the principal lithospheric plates (Africa, Australia, Eurasia, North and South America) are determined with a precision of ± 0.05 mrad/Myr.

## Conclusions and outlook

The new approach for the terrestrial reference frame computation based on time series combination of station positions and EOP has major advantages compared to the past TRF realizations. The advanced methodology allows to account for nonlinear effects in

site motions and ensures consistency between the terrestrial reference frame and the EOP. The results obtained from first comparisons among the ITRS Combination Centres are very promising. However, especially for SLR and VLBI there are several "poorly observed" stations, which should not contribute to the final ITRF2005 solution. Also GPS and DORIS stations with a data time span less than 2.5 years should not be included to ensure reliable velocity estimations. According to the current schedule the ITRF2005 computations will be finalized by the ITRS Combination Centres end of May 2006, followed by a two-weeks validation phase performed by the Technique Centres, before the final ITRF2005 product will be officially released.

## Acknowledgement

The ITRS Combination Centre at DGFI is supported by the Federal Ministry of Education and Research (BMBF), grant 03F0425C within the programme GEOTECHNOLOGIEN.

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