

## 3.6 Combination Centres

### 3.6.1 ITRS Combination Centres

#### 3.6.1.1 Deutsches Geodätisches Forschungsinstitut (DGFI)

The activities of the ITRS Combination Centre at DGFI concentrated on the computations for the ITRF2005. This report contains an overview of the ITRF2005 input data and the combination methodology, some major results of the ITRF2005 solution of DGFI (ITRF2005D), and a comparison of the ITRF2005 solutions of IGN and DGFI.

#### Input data for ITRF2005

Single-technique combined GPS, SLR and VLBI solutions were submitted by the Technique Centres, namely the National Resources Canada (NRCan, IGS), the Institute for Geodesy and Geoinformation of the University Bonn (IGGB, IVS), and the Agenzia Spaziale Italiana (ASI, ILRS). No combined DORIS solution was available by the IDS. Two individual solutions of DORIS Analysis Centres (IGN/JPL, LCA) were provided instead of this. 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 the ITRF2005 input data comprise the local tie information which was provided by the ITRS Centre.

*Tab. 1: Input data sets for ITRF2005 (NNT = no net translation, NNR = no net rotation, NNS = no net scale, NEQ = normal equations)*

| 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 session's free NEQ | 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      | Weekly sol.              | 1993-2005                                      | Station positions<br>EOP (pole, UT1 + rates)              | Loose                                       |
|           | LCA          | Weekly sol.              | 1993-2005                                      | Station positions<br>EOP (pole)                           | 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 consists of the following major steps:

(1) Accumulation of epoch normal equations per technique: In the epoch normal equations velocity parameters were set up and then they were accumulated separately for each technique. Minimum datum parameters were added to generate technique-specific multi-year solutions with station positions, velocities and EOP. In the case of discontinuities position and velocity parameters were set up for the corresponding stations. Time series solutions were computed by transforming the epoch solutions to the multi-year solutions. The resulting time series of station positions and datum parameters were analysed w.r.t. further discontinuities and non-linear effects. A few additional discontinuities were identified during the iterations and considered in the final accumulation.

(2) Inter-technique combination: Input for the inter-technique combination are the accumulated intra-technique normal equations for VLBI, SLR, GPS and DORIS. 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. The intra-technique normal equations are added by applying the weighting factors.

(3) Realization of the geodetic datum: The origin (translation parameters and their rates) is realized by the contributing SLR solutions and the scale and its time variation by SLR and VLBI. The orientation of the ITRF2005 is realized by NNR conditions w.r.t. ITRF2000 using „good“ reference stations to ensure consistency with the Bureau International de l'Heure (BIH) orientation at 1984.0. The kinematic datum of the final ITRF2005 solution is given by an actual plate kinematic and crustal deformation model (APKIM) derived from observed station velocities. A new model (APKIM2005) was computed iteratively from ITRF2005 input data. Fig. 1 shows the residuals of the ITRF2005D station velocities w.r.t. APKIM05D5 for 56 core stations that were used to realize the kinematic datum.

### **ITRF2005 solution of DGFI (ITRF2005D)**

The ITRF2005D solution comprises station positions, velocities and daily EOP estimates as primary results. In addition epoch position residuals and time series of translation and scale parameters are obtained from the combination. Due to the use of discontinuities in the coordinates' time series, many stations get various solutions with different position and velocity estimations. Furthermore co-

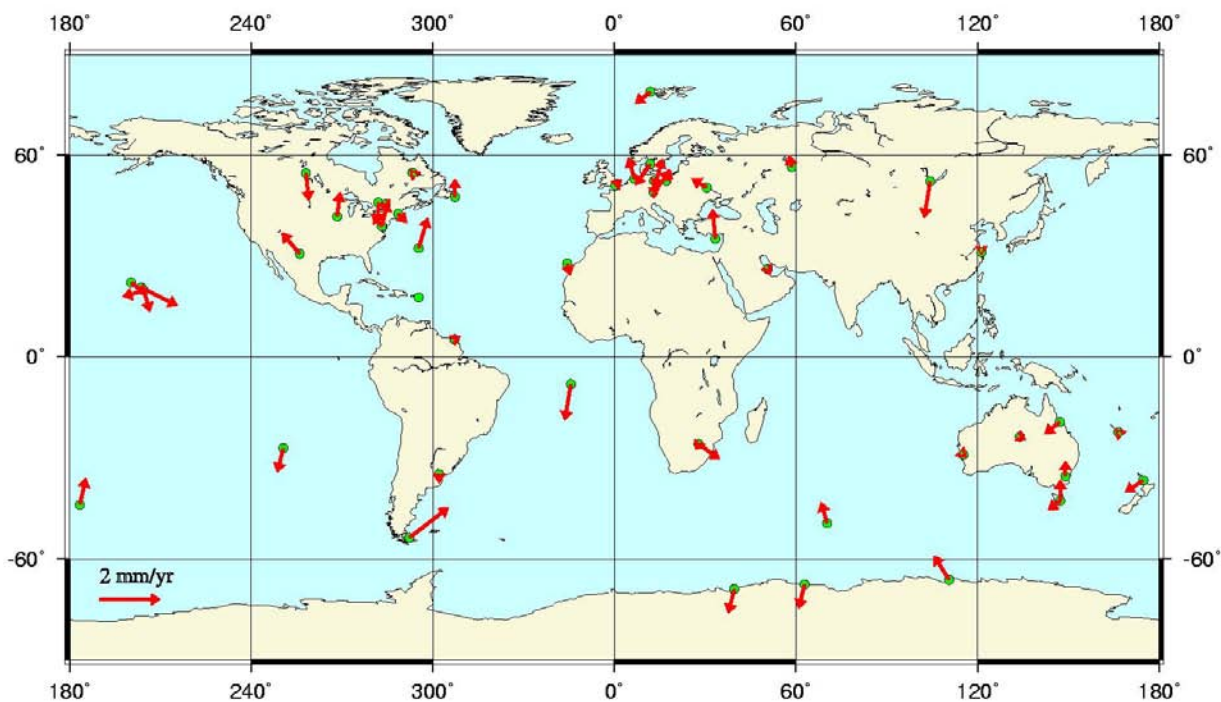


Fig. 1: Station velocity residuals for the 56 core stations, which were used to define the kinematic datum of the ITRF2005D solution w.r.t. APKIM05D5.

location sites may have different station velocities for co-located instruments, if their estimated velocities differ significantly.

Fig. 2 and 3 show the horizontal and vertical station velocities of the ITRF2005D solution. The terrestrial pole coordinates of the ITRF2005D solution w.r.t. IERS C04 are displayed in Fig. 4. There is a significant improvement since mid of 1999, when GPS-derived pole coordinates were included in the combination.

### Comparison of ITRF2005 solutions of DGFI and IGN

Two solutions of the ITRF2005 were computed by the ITRS Combination Centres at IGN and DGFI. The combination 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 and velocities. This method is different from the combination on the normal equation level applied at DGFI.

For comparisons we performed similarity transformations between both solutions. These transformations were done separately for each space technique by using „good“ reference stations. Most of the transformation parameters agree within their estimated standard deviations, except for the scale and its time variation of the SLR network. A significant difference of about 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 in 2006.

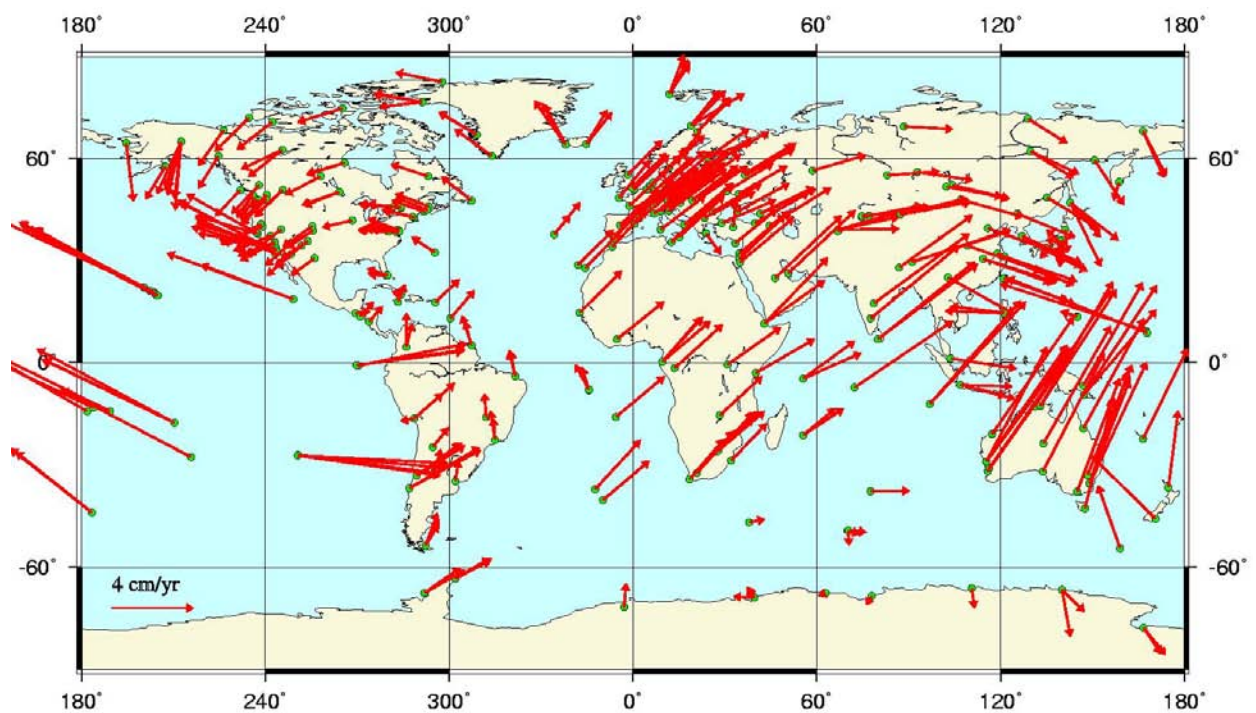


Fig. 2: Horizontal station velocities of the ITRF2005D solution. Note that only velocities with  $\sigma_{vel} < 1$  cm/yr are drawn.

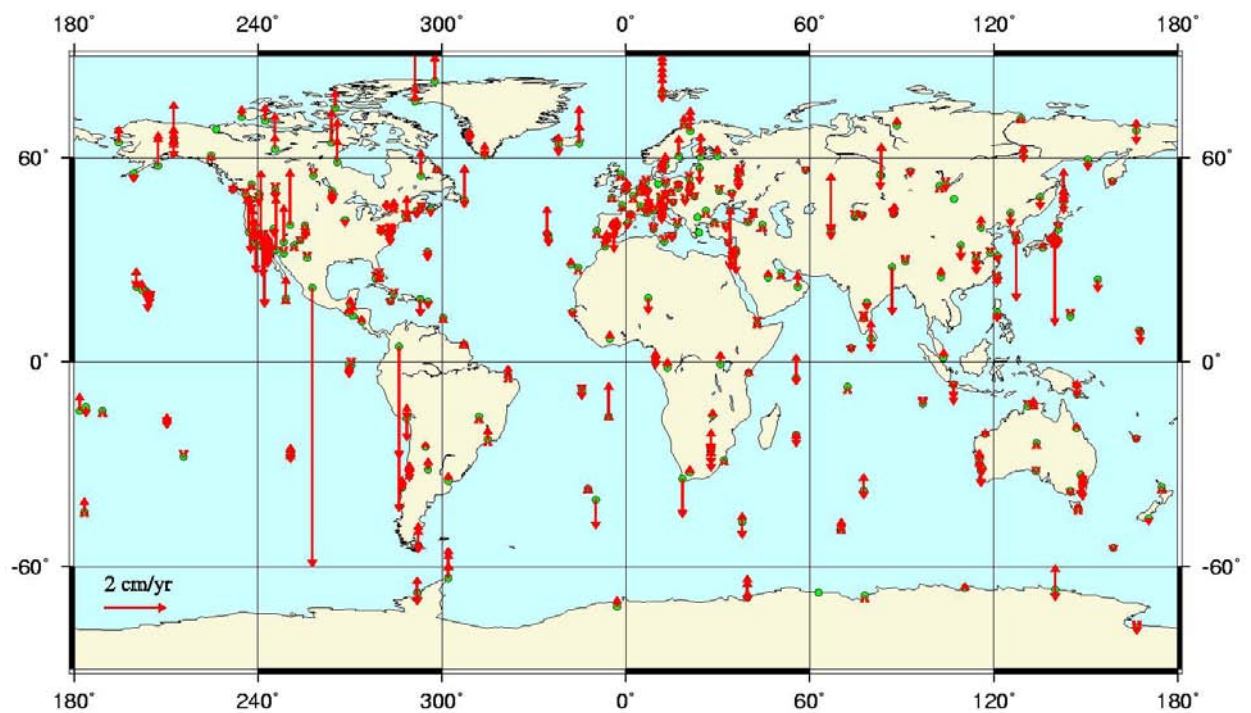


Fig. 3: Vertical station velocities of the ITRF2005D solution. Note that only velocities with  $\sigma_{vel} < 1$  cm/yr are drawn.

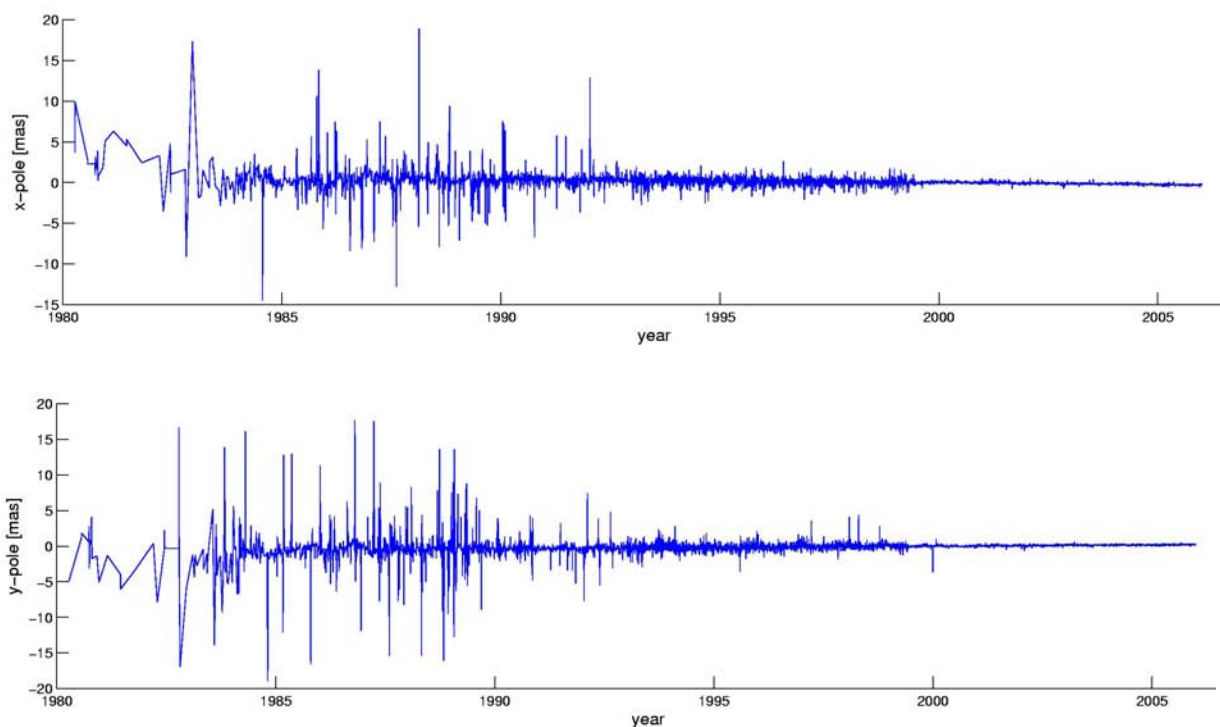


Fig. 4: Terrestrial pole coordinates of ITRF2005D solution w.r.t. IERS C04 series.

The RMS differences for station positions and velocities show a very good agreement (after similarity transformations). This holds in particular for „good“ stations with several years of continuous observations without discontinuities (Table 2). For weakly estimated stations (e.g., observation time less than 2.5 years, or several solutions needed due to discontinuities) larger discrepancies do exist, which however mostly reside within their standard deviations.

Table 2: RMS differences for station positions and velocities between the IGN and DGFI solutions for ITRF2005 for „good“ reference stations (25 VLBI, 22 SLR, 57 GPS, 40 DORIS stations).

| IGN - DGFI         | VLBI | SLR  | GPS  | DORIS |
|--------------------|------|------|------|-------|
| Positions [mm]     | 0.79 | 1.82 | 0.31 | 3.32  |
| Velocities [mm/yr] | 0.34 | 0.66 | 0.14 | 1.11  |

Thus a major problem in the ITRF2005 is the significant difference in the SLR scale. The analysis of weekly SLR solutions of the ILRS Combination Centre (ILRSA) in 2006 has shown that its scale is in reasonable good agreement with the ITRF2005 solution of DGFI, whereas there is a significant scale bias of about 2 ppb w.r.t. the IGN solution (see Fig. 5), which is equivalent to a difference of 1.3 cm in SLR station heights. Because of this discrepancy, IGN provided a second (rescaled) ITRF2005 solution for SLR users.

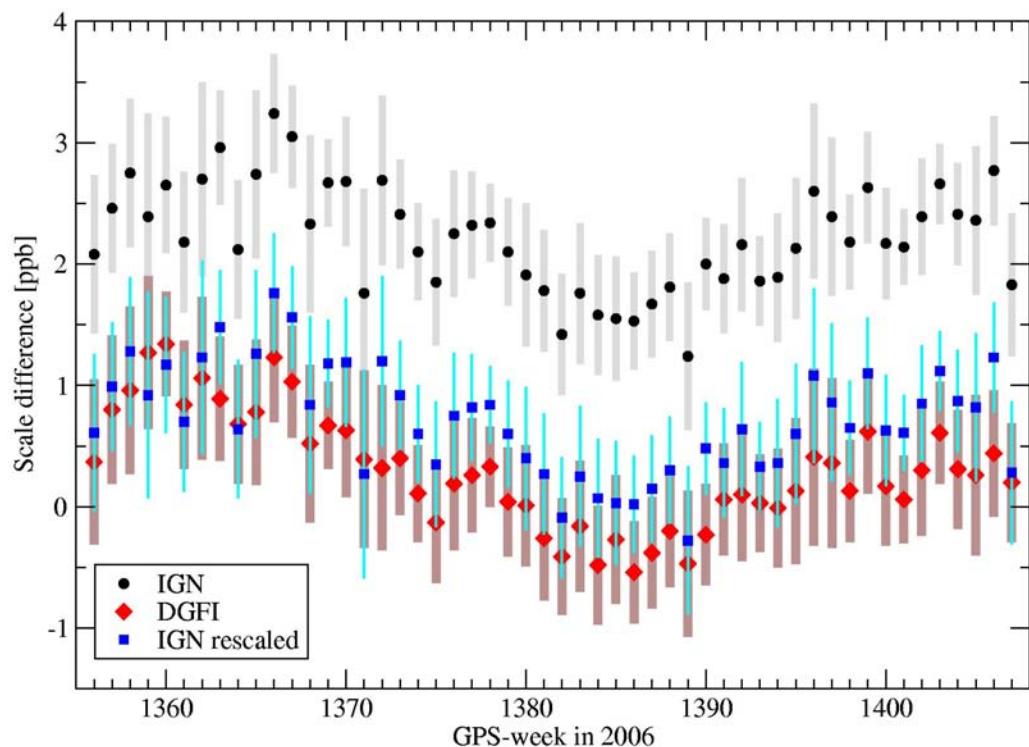


Fig. 5: Scale of ITRF2005 solutions of IGN and DGFI w.r.t. weekly SLR solutions combined by the ILRS Combination Centre A (ILRSA).

The fact, that IGN and DGFI provided each one solution for ITRF2005 using different software and combination strategies has provided for the first time the basis for a decisive validation and quality control of the terrestrial reference frame results. The problem of the significant difference in the SLR scale is subject to further analysis. It has been agreed by IGN and DGFI to perform further test computations to assess the effect of differences in the combination strategies. Since the availability and spatial distribution of high-quality co-location sites is not optimal, the handling of local ties is a very critical issue within the inter-technique combination, which need to be further investigated.

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