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

Report for 2008

In 2008, the major focus of the ITRS Combination Centre at DGFI was on the computation of a new terrestrial reference frame within the German GGOS-D project and its comparison with the ITRF2005. Furthermore, the time series of station positions and the handling of non-linear station motions have been investigated, which is an important issue for future ITRF realizations.

GGOS-D terrestrial reference frame

GGOS-D is funded by the German Ministry for Education and Research in the frame of the programme GEOTECHNOLOGIEN. The project involves four institutions: GeoForschungsZentrum Potsdam (GFZ), Bundesamt für Kartographie und Geodäsie (BKG) in Frankfurt/Main, Institut für Geodäsie und Geoinformation, Universität Bonn (IGG-B), and DGFI. The computation of the GGOS-D terrestrial reference frame is very closely related to DGFI's work performed as ITRS Combination Centre. Input data for the terrestrial reference frame computation are VLBI, SLR and GPS observation time series, which were provided as unconstrained datum-free normal equations (see Table 1). Similar as for ITRF2005, the computation of the terrestrial reference frame consists of the two following major steps:

(1) Accumulation of the time series normal equations per technique and analysis of the time series solutions.

(2) Inter-technique combination of the accumulated multi-year normal equations per technique.

Tab. 1: GGOS-D input data used for the TRF computation.

Technique	Institutions	Software	Data	Time period
GPS	GFZ	Bernese	Daily NEQ	1994 – 2007
VLBI	IGG DGFI	CALC/SOLVE OCCAM	24 h session NEQ 24 h session NEQ	1984 – 2007 1984 – 2007
SLR	DGFI GFZ	DOGS EPOS	Weekly NEQ Weekly NEQ	1993 – 2007 1993 – 2007

GGOS-D terrestrial reference frame compared to ITRF2005

Compared to the ITRF2005 input data, there are some major improvements: (1) The observation time series of the different space techniques were homogeneously reprocessed based on unified standards and conventions; (2) For GPS consistently reprocessed observation time series were used; (3) The modelling of the observations was improved (e.g., absolute instead of relative phase centre corrections, the pole tide model was correctly applied in the VLBI software CALC/SOLVE); (4) The type of input data is nearly identical with the original observation equations and is much more appropriate for the combination than for example loosely constrained solutions or solutions with removable minimum constraints. Another advantage is, that the total number of discontinuities could significantly be reduced compared to the ITRF2005 computation. This was mainly achieved by the homogeneously processed GGOS-D data sets and the implementation of absolute antenna phase centre corrections for the GPS processing.

The results of the GGOS-D terrestrial reference frame computations were compared with the ITRF2005. Figure 1 shows as an example the discrepancies for some of the VLBI and GPS co-locations. For the GGOS-D computations the agreement of the space geodetic solutions with the local ties is better for most stations, which is evidence of the improvements compared to ITRF2005. The results are shown for the ITRF2005 solution of DGFI (ITRF2005-D).

Non-linear station motions

The time series analysis has shown non-linear variations for most of the stations, especially in the height component. Figure 2 shows the mean average shape of such annual variations for four GPS-VLBI co-location sites. These seasonal signals may be caused by atmospherical, hydrological and non-tidal oceanic loading effects, which are not reduced from the original observations. In other cases, instrumentation effects (rather than geophysical ones) may be also responsible for the observed signals.

A deficiency in the current reference frame computation is 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

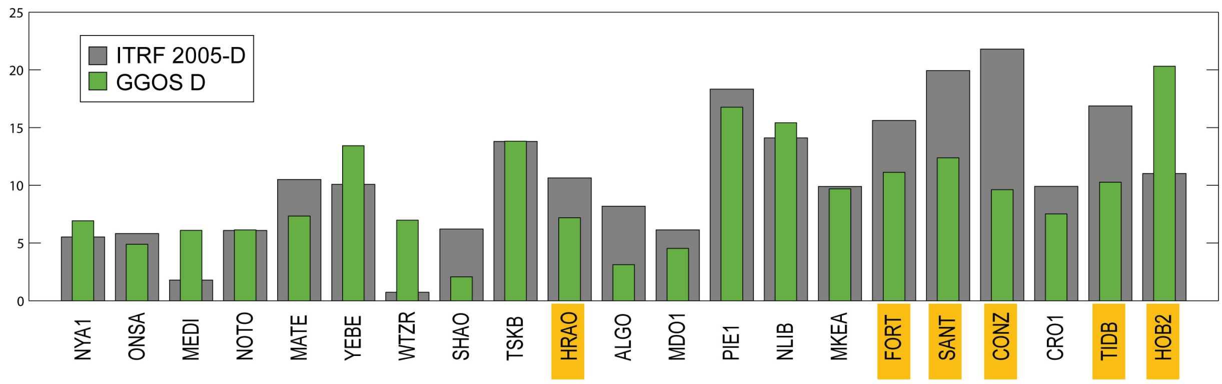

Fig. 1: Comparison of the GGOS-D results with ITRF2005-D. The 3-D difference vectors [mm] between the VLBI and GPS solutions and the terrestrial difference vectors are given for 21 co-location sites. The stations located in the southern hemisphere are highlighted.

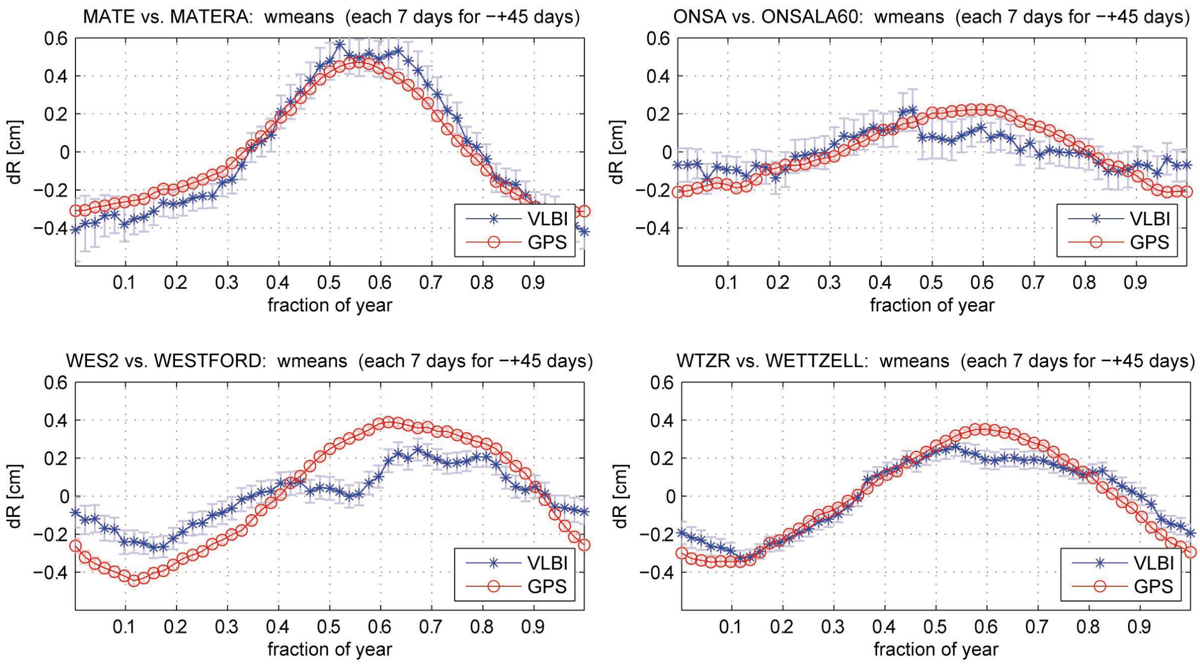

Fig. 2: Mean annual behaviour of homogeneously processed VLBI (blue stars) and GPS (red circles) height time series at four co-location sites. The figures illustrate 90 days moving weighted means and their formal errors, computed each 7 days from the daily height estimates.

combination results. Seasonal variations will affect the velocity estimations, in particular for stations with relatively short observation time spans (i.e., < 2 years). Also the alignment of epoch solutions to a reference frame with positions and constant velocities is affected by non-linear station motions. As shown in Figure 2, the shape of these non-linear motions agrees quite well between VLBI and GPS, but it differs between stations. A suitable handling (parameterization) of the seasonal variations in station positions is a challenge for future ITRF computations.

Acknowledgements

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Report for 2009

In 2009, the focus of the ITRS Combination Centre at DGFI was on the computation of the terrestrial reference frame contribution of DGFI to ITRF2008, DGFI2008. According to the decisions of the IERS Directing Board Meeting No. 51 (2010-10-10, Paris), the individual solutions of the ITRS Combination Centres shall be named by the institution name. The label ITRF is only used for the official ITRF solution in order to avoid confusions.

The combination for DGFI2008 was performed in two major steps: (1) the analysis of input data time series and the computation of one TRF solution per technique and (2) the combination of the techniques to one combined reference frame. Fig. 1 gives a simplified flowchart of the reference frame computation at DGFI. Even if the DGFI2008 was not finished in 2009, the main part of the computation work was done during this year.

Analysis of ITRF2008 input data and computation of one multi-year solution per technique

The input data for ITRF2008 are time series of weekly or session-wise SLR, GPS, DORIS and VLBI solutions or normal equations (NEQ) provided by the individual Technique Centres IVS, ILRS, IGS and IDS. The parameters contained are station coordinates and Earth orientation parameters (EOP). The time series are

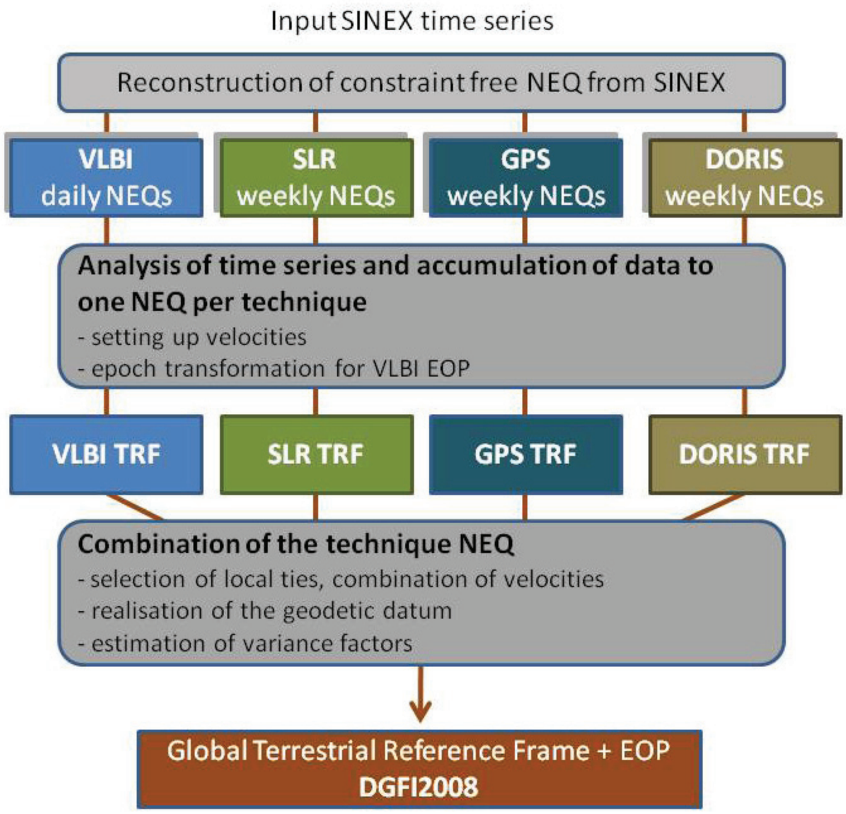

Fig. 1: Simplified flowchart of the computation of the global reference frame, the DGFI contribution to ITRF2008.

provided in SINEX format. For the first time, all input solutions are combined products computed from the contributions of at least 7 Analysis Centres. Tab. 1 gives an overview about the input data.

Tab. 1: ITRF2008 input data.

Technique	Service/TC	Time period	Temporal resolution	Data type
GPS	IGS/NRCan	1997.0–2009.0	weekly	solution
VLBI	IVS/IGG	1980.0–2009.0	24h sessions 24 h session	constraint free normal equations
SLR	ILRS/ASI	1983.0–1993.0 1993.0–2009.0	fortnightly weekly	solutions solutions
DORIS	IDS/CLS-CNES-GSFC	1993.0–2009.0	weekly	solutions

In a first step the normal equations are reconstructed from the SINEX files. In case of IVS the NEQ are provided without datum conditions and the VLBI normal equations can be directly introduced in the combination. The SLR contributions include only loose constraints, which do not have a significant effect on the reference frame solution and thus remain on the NEQ. In case of GPS and DORIS the input data are computed by applying no-net-rotation conditions which are not given in the SINEX. As both techniques shall not be contribute to the datum realization of the reference frame, singularity w.r.t. all the datum parameters (origin, orientation and scale) has to be created by setting up seven datum parameters for each NEQ.

The normal equation time series are solved by applying adequate minimum conditions. The solutions are transformed to the combined reference frame (we start with ITRF2005 and iterate this step using the combined frame DGFI2008). The residual position time series resulting from the transformations are analyzed w.r.t. discontinuities and long-term non-linear station motions (e.g. post-seismic station motions). Fig. 2 gives the number of discontinuities per technique in % of the number of available stations. GPS is the technique affected most by discontinuities.

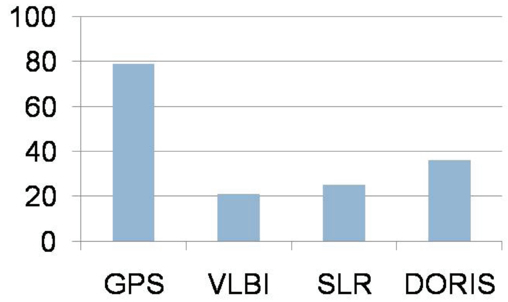

Fig. 2: Discontinuities per technique given in % of the available stations.

In addition to the station position time series also the datum parameter time series are analyzed, in particular those, which should contribute to the datum realization of the DGFI2008 reference frame: the origin and scale of SLR and the scale of VLBI. Fig. 3 shows the scale time series derived from SLR and VLBI. The data at the beginning of the time series are characterized by large standard deviations, thus the systematic effects in the early years do not have a significant impact on the mean scale and both time series are used for the scale realization of the DGFI2008.

The NEQ are accumulated to one NEQ per technique. During this procedure station velocities are set up as additional parameters and identified discontinuities are considered by setting up new position and velocity after the event. Long-term non-linear station movements are approximated by piece-wise linear functions.

Combination of the techniques and computation of the reference frame DGFI2008

The ITRF2008 input data contain station coordinates as well as EOP. Tab. 2 gives an overview about the parameters provided by the techniques.

Whereas the EOP are common parameters, which can be combined directly, station positions can be only combined by introducing terrestrial measurements (local ties) at co-location sites. Fig. 4 shows the global distribution of the technique specific station networks of DGFI2008. The co-location sites and the type of co-location can be seen very well from the superposed symbols.

As the local ties partly show large discrepancies w.r.t. the coordinate difference vectors computed from the space geodetic techniques at co-location sites, only suitable local ties have to be used in the combination. A threshold of 32 mm was assessed as a

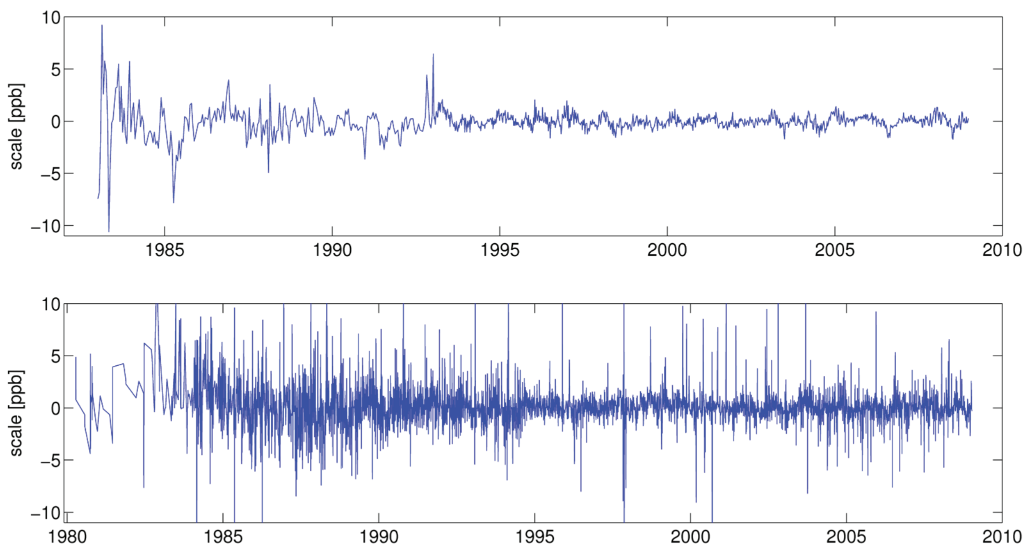

Fig. 3: Scale variation time series of SLR (upper plot) and VLBI (lower plot) w.r.t. DGFI2008.

Tab. 2: Parameters provided by the techniques in the ITRF2008 input data.

parameter	GPS	SLR 1993.0–1993.0	SLR 1993.0–2009.0	VLBI	DORIS
station coordinates	weekly	forthnightly	weekly	24h session	weekly
offsets of terr. pole	daily	3 daily	daily	24h session	weekly
Rates of terr. pole	daily			24h session	
UT1-UTC				24h session	
LOD	daily	3 daily	daily	24h session	
nutation offsets				24h session	

reliable maximum local tie misfit. Fig. 5 shows the number of local ties per continent subdivided into the different co-location types. The lowest three bars (dark blue, red and green) represent the number of co-locations including GPS stations. It becomes obviously, that at all continents co-locations including GPS stations are clearly dominant. This shows, that GPS is the technique allowing to combine the different station networks and thus is essential for the computation of a global terrestrial reference frame.

The computation of the DGFI contribution to ITRF2008, DGFI2008 was finished in 2010. Thus, the final results and comparison to ITRF2008 will be part of the Annual Report 2010.

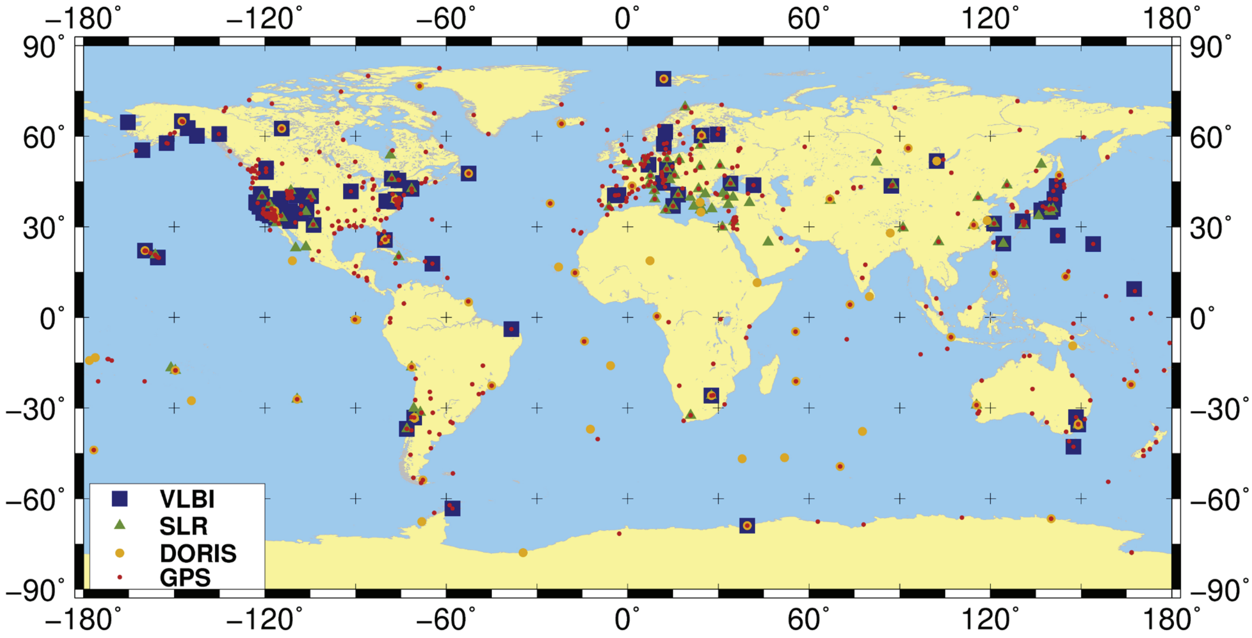

Fig. 4: Global distribution of the technique specific station networks.

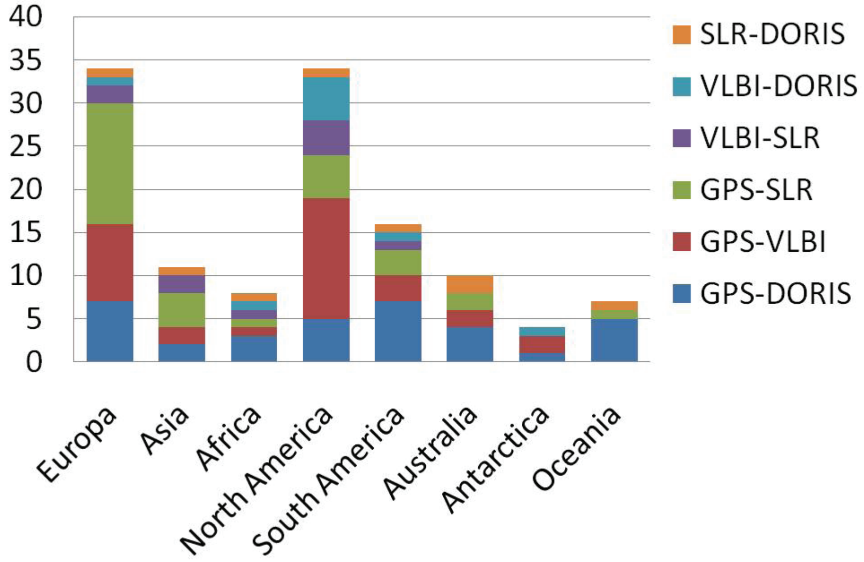

Fig. 5: Number of co-locations used in DGFI2008 per continent.

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