3.6.1.1 Deutsches Geodätisches Forschungsinstitut (DGFI)

In 2012, the focus of the work of the ITRS Combination Centre at DGFI was on continuing the research activities regarding a common realization of the ITRS and ICRS and the computation of epoch reference frames.

Simultaneous computation of CRF and TRF

At present, ITRF and ICRF are computed separately by different institutions which apply different software packages. Additionally, the used input data are not the same. Consequently, the two frames and the respective EOP series are not fully consistent. The main inconsistencies are:

- The input data for ICRF are data resulting from the analysis of VLBI observations at one IVS Analysis Center, AC, (Goddard Space Flight Center). The input data for ITRF are time series, computed by combining the results of the different ACs for each of the geodetic space techniques VLBI, SLR, GNSS and DORIS. The data are provided by the technique services of the IAG. In case of VLBI, the data of six ACs are combined.
- The ITRF and the VLBI-only terrestrial reference frame VTRF - computed consistently to the ICRF - differ with respect to the network scale. It is realized from VLBI data only in case of VTRF and as a mean of the VLBI and the SLR scale in case of ITRF. Additionally, the network geometry of VTRF and ITRF differ slightly, as the geometry is marginally changed in the combination.
- The EOP derived from ICRF computation are VLBI-only EOP series. Due to the fact, that VLBI does not provide continuously observations, the EOP series are also not continuous. The EOP solved consistently to the ITRF are combined EOP series of VLBI, SLR, GNSS and DORIS, which are continuous for the satellite era.

A consistent computation of TRF and CRF from long time series of VLBI, SLR and GNSS input data (normal equations) was performed at DGFI. While the combination of the station coordinates does not have a systematic effect on the CRF, the EOP combination leads to changes in the standard deviations and positions of the source coordinates:

- The combination of the EOP leads to a general decrease of the standard deviations of the source positions. As expected, the VCS sources (Fig.1), usually showing standard deviations which are about 5 times larger than those of the non-VCS sources, benefit most. About 90% of the effect can be related to the combination of the terrestrial pole coordinates.
- The source positions are also changed by the combination of the EOP. While in declination no systematic effect is found, some of the VCS sources show systematics in right ascension, mainly caused by LOD combination. But also the combination of the terrestrial pole coordinates lead to small systematics (see Fig.3).

Figure 4 shows the correlation matrix of the source positions. While the non-VCS sources show correlations of up to 0.9, the correlations between the VCS sources are very small. Its interesting that the group of VCS sources is better linked to the non-VCS sources than the VCS sources among themselves. A re-observation for the VCS sources in new constellations would help to link the VCS sources much better and would lead to a homogeneous CRF, which is not split into several groups of sources.

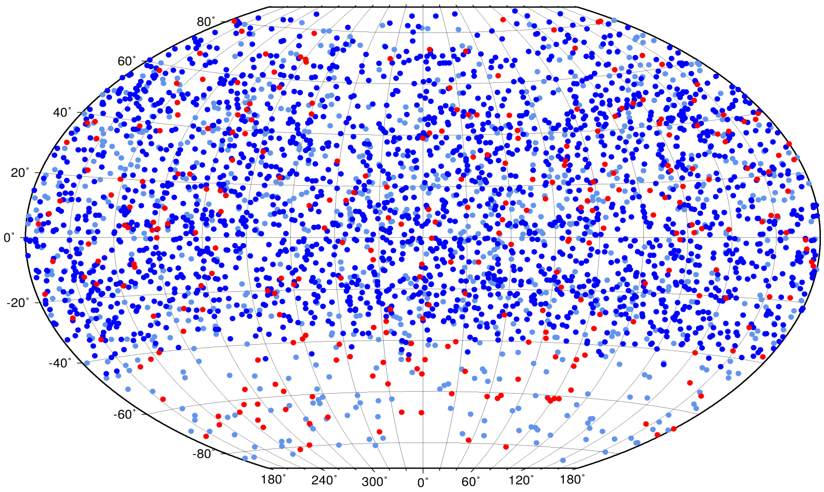

Fig. 1: Celestial reference frame (CRF): VCS sources (dark blue) observed by the VLBA station network (Fig. 2), non-VCS sources (light blue), defining sources (red).

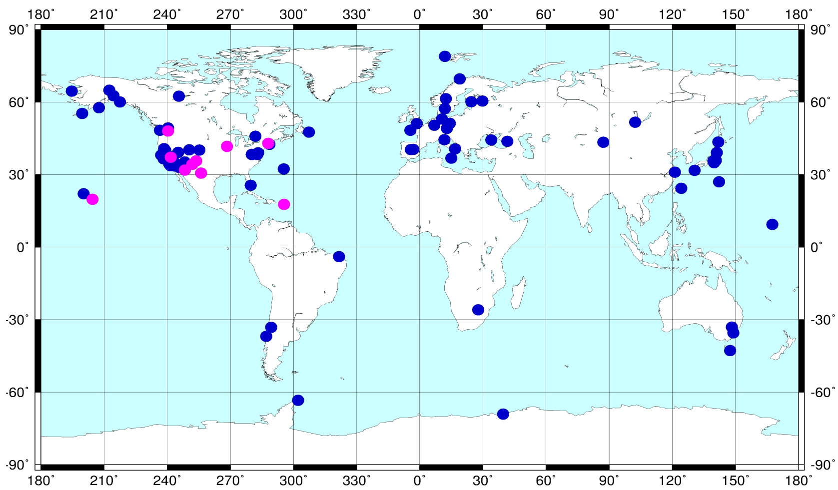

Fig. 2: Global VLBI station network. The stations of the VLBA network are magenta-colored.

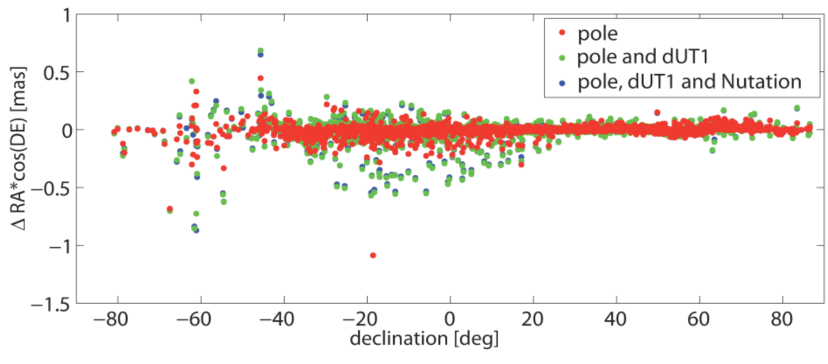

Fig. 3: Effect of the combination on the CRF: Change of right ascension due to different kinds of EOP combination: only terrestrial pole coordinates are combined (red), terrestrial pole coordinates and UT1-UTC parameters are combined (green), all EOP, i.e. coordinates of the terrestrial and the celestial pole and UT1-UTC are combined (blue).

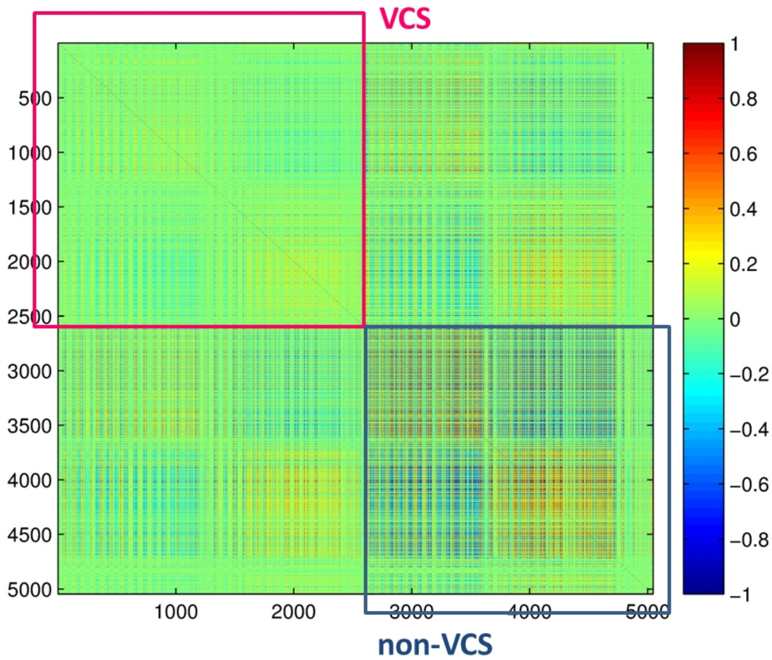

Fig. 4: Correlation matrix of source positions sorted by VCS and non-VCS sources.

Epoch reference frames (ERFs)

State-of-the-art realizations of terrestrial reference frames (TRFs) realize the motion of a reference point, connected with the Earth's crust, by a constant velocity. Global and environmental deformations of the crust (e.g., due to tides and loading effects) affect the short-term and long-term motion in a periodic manner. Additionally, aperiodic motions are caused by earthquakes or by man-made changes, such as technical updates of a station. Since these variations cannot be taken perfectly into account by models, the residual variations propagate into the observation residuals or falsify other consistently estimated parameters such as the Earth Orientation Parameters (EOP). To study the impact of non-linear station motions on the EOP, one possibility is to estimate the station position frequently (e.g., weekly). In this alternative station parameterization, the station motions are approximated by a time-discrete signal. Figure 5 shows the differences $d(t_i)$ between the conventional parameterization $X_R(t_i)$ used for e.g., the International Terrestrial Reference Frame 2008 (ITRF2008) and the parameterization $\tilde{X}(t_i)$, used for the most recent realization of the DGFI ERFs.

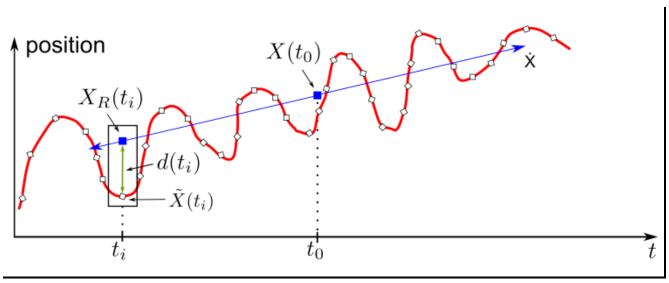

Fig. 5: Different station motion parameterization in the conventional reference frame realizations (such as ITRF2008), $X_R(t_i)$, and DGFI ERFs, $\tilde{X}(t_i)$.

The differences $d(t_i)$ can be separated into three constituents (Fig. 6):

$$d(t_i) = d^{stat}(t_i) + [\Delta CF(t_i) + h(t_i)] \quad , \tag{1}$$

with the individually performed non-linear station motion $d^{stat}(t_i)$ caused by local environmental effects (e.g., groundwater withdrawal), the non-linear height variation $h(t_i)$ common to all stations which not affects the Center of Frame (CF) but the network scale λ and the non-linear variation of the CF w.r.t. the Center of Mass of the whole Earth $(CM \equiv 0)$ caused by non-linear motions common to all stations.

The CF is defined not to be the barycenter of the station network but the Center of the best-fitting ellipsoid through the station coordinates. Depending on the network geometry (station distribution), the origin of the network is correlated with the orientation of the network (Fig. 6). Since the network orientation in x - and y -direction and the terrestrial pole coordinates y and x are complementary parameters, variations in the origin of the network affect the terrestrial pole coordinates.

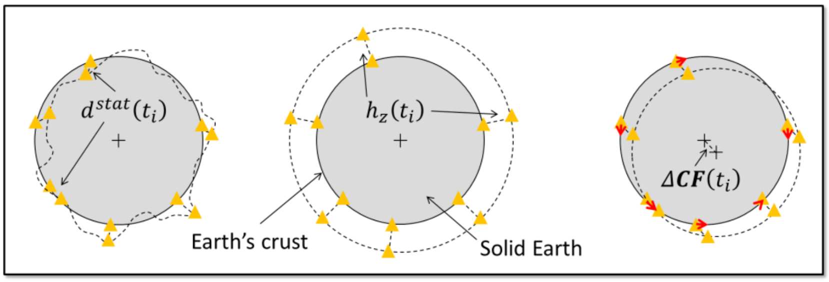

Fig. 6: The three constituents of $d(t_i)$ *. Common translations* $\Delta CF(t_i)$ *can cause rotations (red arrows in right panel) common to all stations (triangles) in the conventional parameterization.*

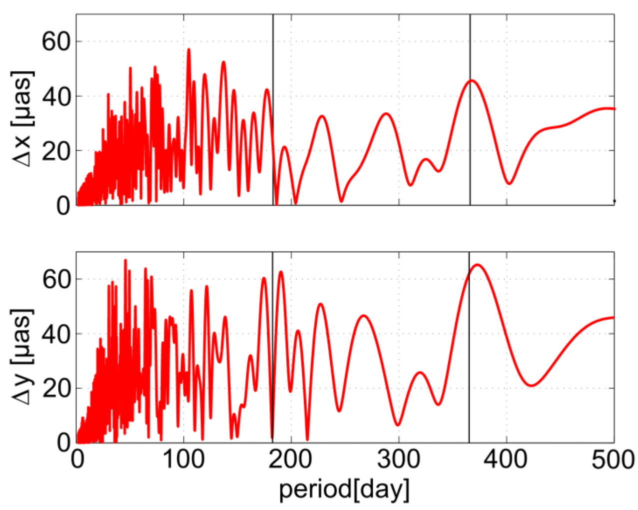

Fig. 7: Amplitude spectra of the x *- and* y *-pole difference time series using the conventional and the ERF station parameterization (Fig. 5). Amplitudes of* $10.0\,\mu as$ *are equal to a distance of* $0.3\,mm$ *at the Earth's surface.*

The above described relationship plays an important role especially for Satellite Laser Ranging (SLR). Since this technique is sensitive to the CM and the global station distribution is not homogeneous, the differences $d(t_i)$ excite a clear seasonal variation (Figure 7) with amplitudes of $1.43\,mm$ in the x -pole and $2.02\,mm$ in the y -pole, respectively. The seasonal period is caused by the mainly seasonal character of the differences $d(t_i)$ since in this analysis, the loading displacements due to the atmosphere and the hydrology are not considered. The signals with periods lower than the seasonal frequency band reach still amplitudes of up to $2.0\,mm$ and are influenced to a larger extend by the individual station motions $d^{stat}(t_i)$.

The results of this analysis show that the EOP of the conventional TRF realization are affected by the not-parameterized non-linear station motions. Nevertheless, the TRF realizations are, due to their high long-term stability, fundamental for monitoring long-term changes within the Earth's system.

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Authors: Manuela Seitz, Detlef Angermann, Mathis Bloßfeld, Michael Gerstl, Horst Müller