GGOS-D Reference Frame Computations

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1. Introduction

Reference frames of high accuracy are the basis for the analysis and interpretation of geodetic parameters and their temporal behavior. Modern reference frames are generated by combining the data of the space geodetic techniques VLBI, SLR and GPS. The consistency in time of the analysis strategies for each data series but also between the techniques is essential to obtain a reference frame of highest accuracy. The International Terrestrial Reference Frame (ITRF2005) is not based on such homogeneous data sets. Thus, the computation of a reference frame within the GGOS-D project is fundamental for the analysis of the results. The adaptation of the software packages is an extensive part of this project. Examples are given in Nothnagel et al. (2007).

2. Global terrestrial reference frame (TRF)

The computation strategy for the terrestrial reference frame is displayed in Fig. 1. In a first

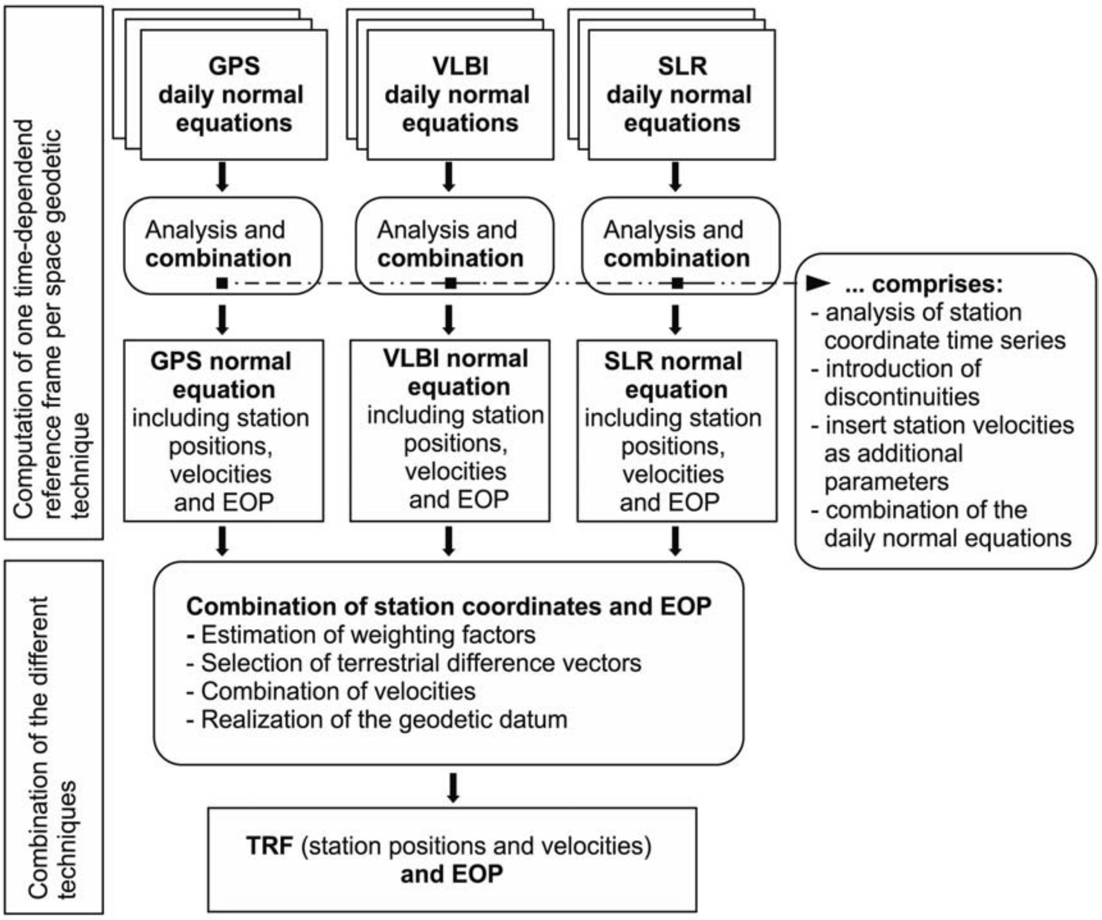

Figure 1: Scheme of the terrestrial reference frame computation

part of the processing daily or weekly normal equations are combined to a multi-year solution separately for each technique. The most important task in this step is the adequate modelling of the temporal behavior of the station coordinates (Meisel et al., 2007).

In the second part the technique normal equations are combined to a terrestrial reference frame. Here, the selection of terrestrial difference vectors (local ties) in view of accuracy and consistency of the combined solution is the most complex problem, which has to be solved. A detailed description of the strategy is given in Angermann et al. (2007).

a) Modelling of station positions

An important part in the computation of a terrestrial reference frame is to identify and consider discontinuities in the station coordinate behaviour. We started with a discontinuity table provided by each technique, the same as was done in the ITRF2005 computation at DGFI (ITRF2005D, see Meisel et al., 2007). In the ITRF2005 computations a large number of discontinuities had to be introduced, which were apparent in the station position time series but could not be correlated with an instrumental or geophysical cause. This is especially the case for GPS, where 221 discontinuities are applied for 332 stations in the ITRF2005D solution. With the consistent data sets of GGOS-D this could be reduced to 124 discontinuities in 240 stations.

A further important task is to introduce discontinuities in a similar way for different techniques, especially stations with earthquakes such as Arequipa or Fairbanks. The problem is, that not only the jump caused by the event but also the post-seismic nonlinear movement of the station has to be modelled. Especially Fairbanks is critical to VLBI, as it was one of the stations used the most and thus important for UT1 determination.

ITRF2005 was computed using the traditional parameterization of station positions at a reference epoch and constant velocities. It is clear that the station positions show variations that cannot be accounted for by a linear model. So the question arises, how we can extend the existing model. One possibility is to estimate sine/cosine functions with a period of one year in addition to the linear velocities. To investi-

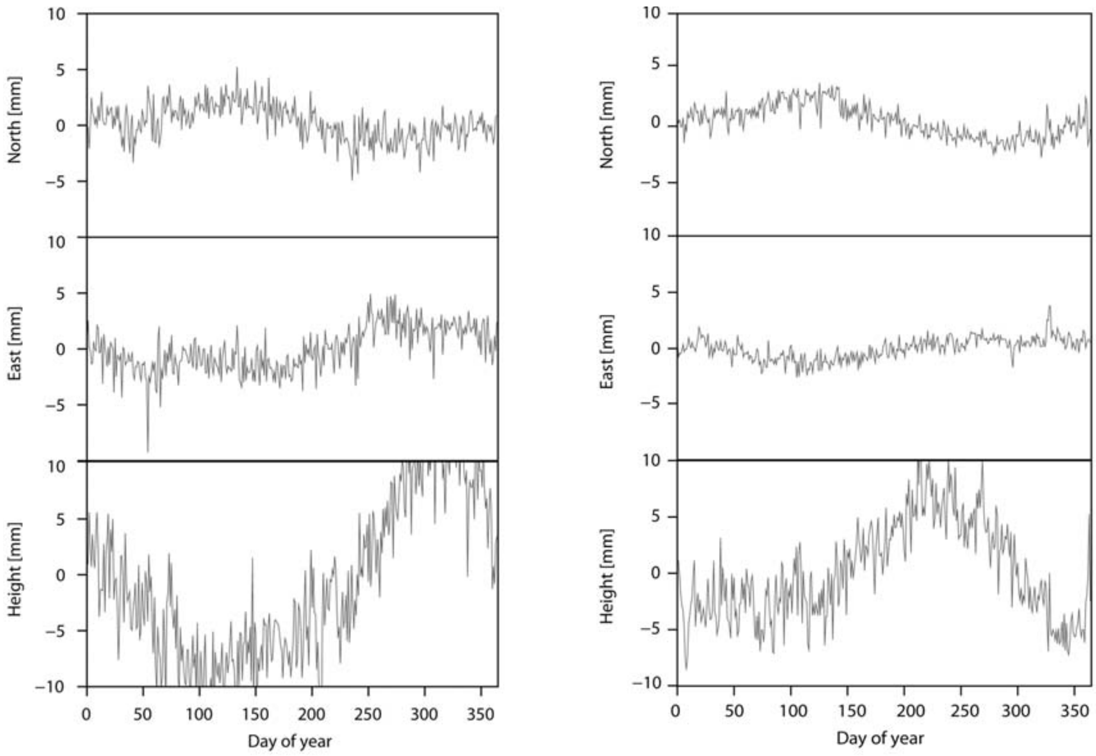

Figure 2: Mean annual signals of the two GPS stations Brasilia (left) and Ankara (right)

gate this we compute a mean annual signal of the GPS time series for each station.

The results show for most stations a small signal (few millimetres amplitude) in the north and east component that has the shape of a sine/cosine function. The variation in the height component is somehow larger (few millimetres up to 1–2 centimeters). The majority of stations show a characteristic seasonal signal that is somehow asymetric (see example Brasilia in Fig. 2). But there are also stations that show either two maxima/minima in one year or a flat curve for half of the year and a maxima in the other half (see station Ankara in Fig. 2).

b) Selection of terrestrial difference vectors for the combination of the different space techniques

For the combination of the station networks of different space geodetic techniques, terrestial difference vectors between the reference points of the different instruments at co-location sites are necessary. As for some of the co-locations the difference vectors do not fit well to the estimates of the space geodetic solutions, a selection of difference vectors is essential to obtain a TRF of high accuracy. Fig. 3 shows the discrepancies for some of the GPS-VLBI co-locations. Additionally, the corresponding discrepancies derived from the ITRF2005 computations at DGFI are displayed. Especially for the co-locations at the southern hemisphere the discrepancies are smaller than in the ITRF2005D, except for station Hobart (HOB2). For some of the co-locations in Europe the discrepancies become a bit larger, compared to ITRF2005D. The reason for the differences are changes in the modelling of the space geodetic techniques. The most important ones are the switch from relative to absolute phase center corrections for GPS antennae (Steigenberger et al., 2007) and the change of the pole tide model in the VLBI data (Böckmann et al., 2007). Both lead to changes in station coordinates of up to 1 cm.

To select useful terrestrial difference vectors two criteria are defined, which have to be fulfilled by the set of difference vectors: 1) the consistency of the combined solution must be maximal and 2) the deformation of the network due to the combination should be minimal.

To investigate the consistency, the station networks of the techniques are combined but not the EOP. The mean difference between the pole coordinates is an expression of the consistency and must be minimized. The deformation can be quantified by the mean residuals resulting from a similarity transformation between the combined and the one technique only solutions.

To identify the best set of co-location sites, different solutions are computed, varying the co-locations and the assumed accuracy of the introduced difference vectors. Five sets of difference vectors are selected, which fit the estimates of the space geodetic techniques within 8, 10, 12, 14 and 18 mm, respectively. The a priori formal errors of the vectors is varied

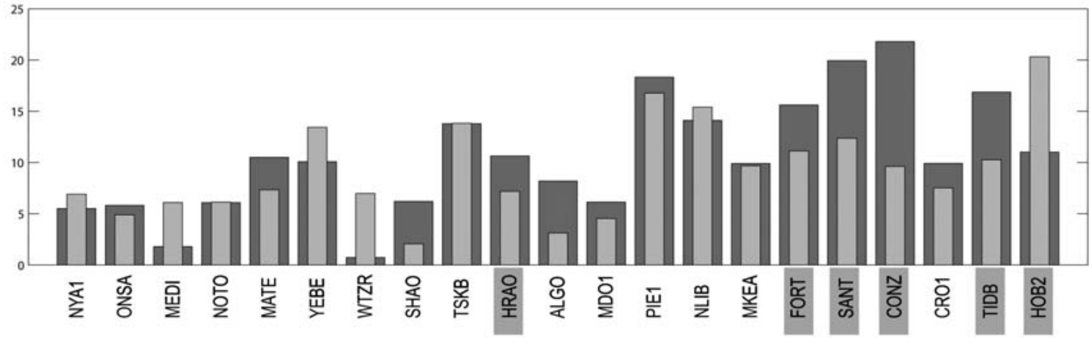

Figure 3: Differences [mm] between terrestrial difference vectors and the coordinate differences derived from GPS and VLBI solutions at co-location sites. Green: GGOS-D data. Grey: ITRF2005D. The sites are named by the 4-character ID of the GPS station. Stations of the southern hemisphere are marked by an orange background

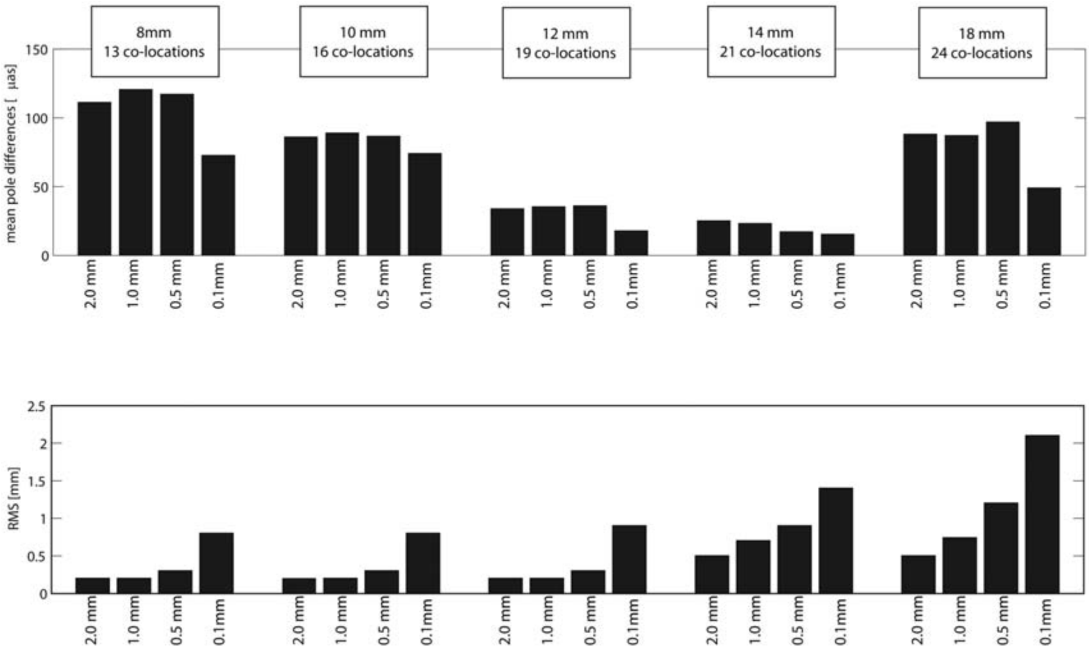

Figure 4: Mean pole coordinate differences and mean residuals of station coordinates resulting from the similarity transformation between the combined and the VLBI-only solution for different solution types

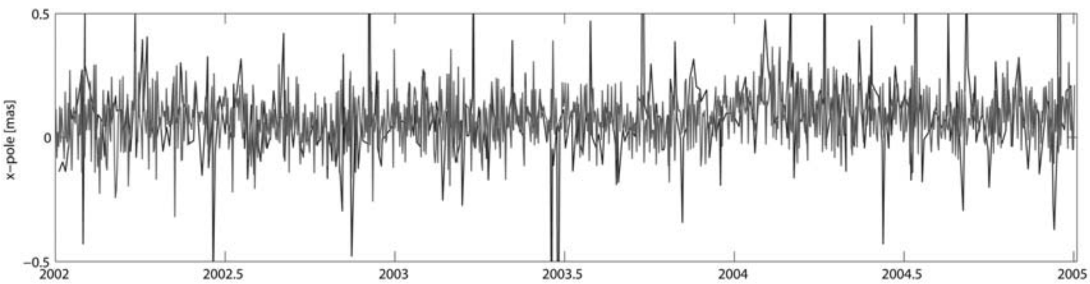

Figure 5: Time series of x-pole coordinates wrt. IERS C04 derived from GPS (red) and VLBI (blue) for the years 2002 to 2005. The station networks of both techniques are combined

from 0.1 to 2 mm. Fig. 4 shows the results of this analysis. The solution obtained introducing a set of difference vectors, that fit to the space techniques within 12 mm with an accuracy of 2 mm gives a small pole difference and the smallest deformation of the station network. Thus, this solution type is used for the computation of the reference frame.

The GPS and VLBI time series of the x-pole derived from this solution are displayed in Fig. 5. They show an excellent agreement.

3. Celestial reference frame (CRF)

The common computation of the terrestrial and the celestial reference frame in one adjustment guarantees consistency between the two frames as well as the corresponding Earth rotation parameters. As only the VLBI technique provides an access to the CRF, a common adjustent of both frames was performed using VLBI data. A minimum datum was applied to the station coordinates (no-net-rotation and no-net-translation condition) as well as to the quasar coordinates (no-net-rotation-condition) to obtain undeformed reference frames.

Such a solution reveals correlations between coordinates of single stations and sources, which are due to an insufficient redundancy in the observation geometry (mainly for stations or sources in the south). Most of such stations did not observe in sufficiently varying networks, weak sources often were only observed by one or two baselines. A combination of the VLBI station network with other space geodetic techniques, especially GPS, will stabilize the weakly determined VLBI stations and thus the southern radio sources. Even more stability can be achieved, if the troposphere parameters of GPS and VLBI are also combined (Krügel et al., 2007).

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