GPS and VLBI results for geodynamic studies

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92th "Journées Luxembourgeoises de Géodynamique" JLG, November 8-10, 2004 Luxembourg.

Global positioning system (GPS) and very long baseline interferometry (VLBI) have reached such a high level of observational precision, that most remaining problems are model-induced. The objective of this study was in a first step to compare site coordinate changes with special treatment of constraint handling and reference frame realization; secondly, to test different existing atmospheric loading models, and finally to investigate baseline length changes, which are invariant to rotations and translations, and their benefits versus position coordinates. Our goal was to check the quality and to evaluate the usefulness of GPS and VLBI solutions for global geophysical investigations.

On the one hand, each of the eight International GPS Service (IGS) Analysis Centres (ACs) produces a global weekly coordinate solution in the Software Independent Exchange (SINEX) format, which contains parameter vectors, a so-called "full" estimated and a priori covariance matrix. The latter should normally allow us to remove a priori constraints to produce a free network solution. On the other hand, we calculated two daily solutions of VLBI sessions with the OCCAM 6.0 lsm software. Sessions from November 1981 till June 2004 are included. No sessions with less than 3 stations have been used. The total number of resulting stations sums up to 47, while the number of sessions amounts to 3045. A priori source coordinates have been fixed to the ICRF. Station coordinates are estimated free, but six no-net-rotation (NNR) and no-net-translation (NNT) minimal conditions were imposed on the adjustments of site positions in order to solve the LSQ problem of incomplete rank. The Vienna Mapping Function (VMF) has been used as tropospheric model. The VLBI solution, with atmospheric pressure loading corrections applied, has been produced through the computation and reduction of theoretical time delays. The IGG (Institute of Geodesy and Geophysics) VLBI solution has been checked versus the Goddard group (GSF) baseline solution. GPS weekly SINEX files contain typically 10.000.000 observations for 100.000 unknowns, whereas daily VLBI files contain only 1000 observations for 300 unknowns.

Most IGS ACs constrain more than minimally their weekly SINEX solutions, which are free downloadable over the Internet. These solutions are distorted and are not directly usable for precise geophysical investigations. Subtracting the inverse of the estimated and constraint matrices removes surplus constraints. The resulting unconstrained matrix should be singular, due to rank deficiency (3 rotations). To complete this rank deficiency minimum constraints are added to obtain the minimally constrained variance matrix, involving appropriate columns of the design matrix of partial derivatives constructed upon approximate station positions (attention to the IERS Conventions 2003 for the rotation direction of axes). One assumption in this procedure is, however, that the complete normal equation matrix (including all parameters) consists of a block diagonal structure. This assumption is not assured. High correlations between different-type estimated parameters exist, i.e., polar motion components and station coordinates.

The common IGS terrestrial reference frame is called IGb00 and includes 99 station positions and velocities. It has been aligned to ITRF2000 at epoch 1998.0 using an unweighted 14-parameters transformation. In order to compare different free network solutions, transformation parameters have to be determined between the various ACs and IGb00. It is important to point out that IGb00 is not a subset of ITRF2000, i.e., it includes other stations, too. The effect of the number and quality of stations contributing to realize a reference frame is often underestimated. Transformation parameters vary to a non-negligible degree after eliminating sequentially the worst common station from the estimation process, and reprocessing the transformation parameters. A scale change of 1 ppb corresponds to 6.3 mm variation of the vertical on Earth's surface. It is impossible to compare topocentric station coordinates variations of various ACs at the aimed level of precision: we are not able to discern between real and artefact crustal motion on individual sites. Unreported changes in software models strategies even make the problem worse, i.e., a change in resolving ambiguities produces visible jumps in coordinate time series. A reanalysis of the complete GPS time series will surely contribute to a better understanding.

The Special Bureau for Loading (SBL) provides official time series of 3D atmospheric loading, generated using a global convolution of NCEP Reanalysis data and Farrell's elastic Green's functions. Besides, the Goddard VLBI group (GSF) provides also equivalent time series. These GSF time series are used in the OCCAM 6.0 lsm software. Differences in atmospheric loading values, between both groups, are in general below the 2 mm level for the radial component. However, for some stations maximum temporal deviations show up in the order of 10 mm, i.e., station OHIG. The differences in the horizontal components are below the 1 mm level.

For the GPS technique, we processed baselines repeatability of the IGS solution for the epoch 2000.5-2004.5 providing more than hundred data points, resulting in more than 14000 baselines. The dependence between repeatability and baseline length has an obvious linear pattern. The repeatability of the baseline length for the GPS technique is at a level of 1mm + 5E-10 times baseline length [mm]. The GPS baseline solution shows a much smoother variation than the VLBI. Although the number of data points is nearly identical for both techniques, we must recognize that GPS is a weekly solution whereas VLBI is a daily solution with only 1 to 2 observation days per week.

The purpose of SINEX is merely to provide information about how the solution was done. The problem of SINEX is that it is rigid: it does not allow describe new parameters. The SOLUTION/MATRIX_APRIORI block is an inverse of the weight matrix, but the weight matrix can be singular and therefore, the inverse does not exist. There cannot be an a priori covariance matrix if we apply singular constraints, e.g., NNR.
The terrestrial reference frame e.g., IGb00 model, can still be improved through the joint VLBI and GPS baseline trend estimation results. GPS and VLBI baseline trends agree to a very high degree, but both differ from the a priori IGb00 (ITRF2000) model. This potential, based on baselines, should be considered for future terrestrial reference frame realizations.
And finally, available GPS and VLBI software packages still need further checks and extensions.