3.6 Combination Centres

3.6.1 ITRS Combination Centres

3.6.1.1 Deutsches Geodätisches Forschungsinstitut (DGFI)

Background and major activities

The work of the ITRS Combination Centre (ITRS CC) at DGFI is being funded by the Geotechnologien-Projekt of the German BMBF (Bundesministerium für Bildung und Forschung), Verbundprojekt: FE: IERS, Forschungsvorhaben: 03F0336C. The activities are closely related to the IERS Combination Research Centre at DGFI (see 3.6.2.2, this issue). This ensures that the state-of-the-art combination strategies, algorithms, software packages, etc. can be applied for the computation of the ITRS products.

This report summarizes the activities of the ITRS CC during the year 2002. They can be divided into two major topics:

- Software enhancement and further developments of the combination procedure of the ITRS CC;
- Data analysis and computation of a combined TRF solution.

Software enhancement and further developments of the ITRS CC

During the year 2002 a major part of the work was related to further developments of the ITRS Combination Centre, including software enhancement, refinements of the combination methodology, further automation of the processing and data flow, as well as improvements of tools and software for quality control and validation of the combination results. The combination procedure, the processing flow and the relevant software packages are shown in Figure 1.

The relevant software and tools of the ITRS Combination Centre can be structured in two parts:

- Validating, unconstraining and reformatting software:
  - SNXCHK: Checking of SINEX files
  - SNX2DOGS: Reformatting of SINEX format into DOGS format and generation of unconstrained (free) normal equations
  - DOGS2SNX: Reformatting of DOGS into SINEX format
- Relevant packages and modules of the software DOGS (DGFI Orbit & Geodetic Parameter Estimation Software):
  - DOGS-AS (**A**nalysis of **S**olutions): This program package delivers tools for the analysis of individual and combined space technique solutions and/or normal equations (e.g. rank defect analysis, deconstraining normal equation matrices, variance component estimation for inter-technique combination).
  - DOGS-CS (**C**ombination & **S**olution): This software package consists of various programs to combine and solve normal equation systems obtained from the same and/or different observation types (e.g. VLBI, SLR, GPS, DORIS). DOGS-CS enables a number of features for the combination of space geodetic data and/or solutions (e.g. elimination or reduction of param-

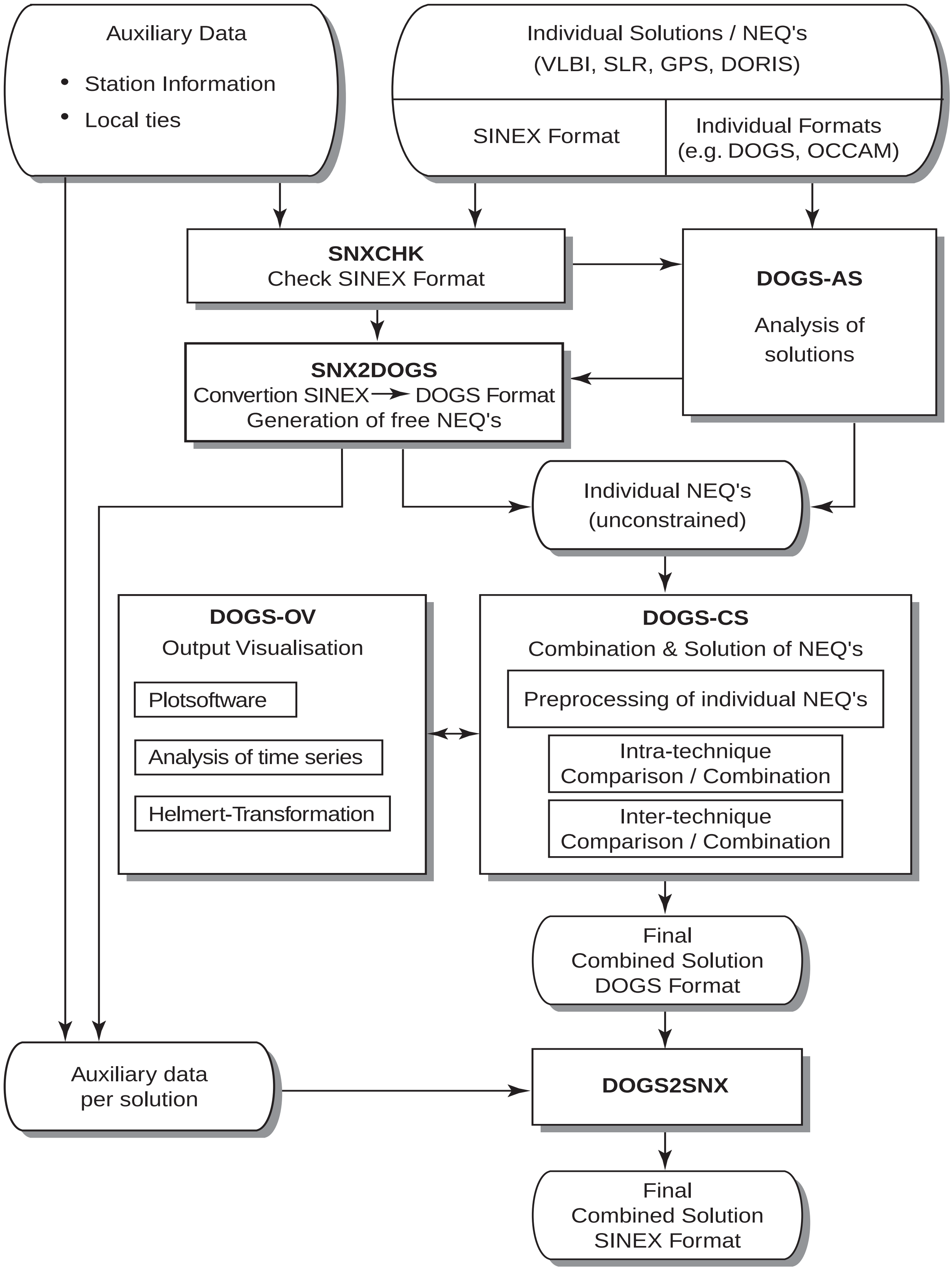

Figure 1: Data flow and combination procedure of the ITRS Combination Centre at DGFI.

eters, equating parameters, parameter transformations, flexible handling of local tie information and datum conditions).
- DOGS-OV (**O**utput **V**isualisation): This software package consists of various programs and tools for the analysis, validation, quality control and graphical representation of the combination results (e.g. Helmert transformation, plot software, analysis of time series).

The combination methodology of the ITRS Combination Centre at DGFI is based on the following major steps (see Figure 1):

- Validation and analysis of individual solutions: The available solutions are checked concerning various aspects, such as format and the suitability for a rigorous combination.
- Reconstruction of unconstrained (free) normal equations: According to our combination strategy on the level of free normal equations we have to remove the datum constraints which are applied to the solutions.
- Preprocessing of individual solutions: For some of the input solutions it may be necessary to perform preprocessing, e.g. transformation of a particular solution (normal equation) to the reference epoch of the combined solution, a-priori reduction of stations with very poor observations (e.g. < 1 yr), which should not be included in the TRF computation.
- Intra-technique comparison/combination: The input for it are individual unconstrained normal equations of the same observation techniques. Before combining them, a dedicated comparison is essential to identifiy possible problems, which could cause systematic effects (biases) onto the combined result. Unremovable datum biases are overcome by introducing Helmert parameters for the individual solution. In order to generate comparable individual and intra-technique solutions we define the datum for each of them in a consistent way by applying minimum constraints. Other important tasks are the computation of relative weighting factors for the individual solutions and the identification and reduction of outliers. Finally, the individual normal equations are added by applying the previously estimated relative weighting factors.
- Inter-technique comparison/combination: The input for it are the combined intra-technique normal equations (unconstrained) resulting from the previous processing step. Similar to the intra-technique case, a dedicated comparison of the solutions of the different techniques (especially at colocation sites) is necessary to identify possible problems. Other important tasks include the estimation of relative weighting factors (e.g. variance component estimation), handling of local ties, equating velocities of different occupations and/or techniques on the same

site, and the datum definition. The combined intra-technique normal equations are added by applying relative weighting factors between the different techniques. The resulting free normal equations are completed by pseudo-observation equations for local ties and for equating velocities (at one site).
- Final combined solution: To generate the final combined solution we add datum conditions and invert the resulting normal equation system. We define the geodetic datum by no-net-rotation conditions for the orientation and its rate with respect to ITRF2000 station positions and velocities. The origin (translation and their rates) is defined by SLR, and the scale and its rate by SLR and VLBI. Currently, we do not use GPS and DORIS solutions to define the datum of the combined solution.

Data analysis and computation of a combined TRF solution

The purpose of that exemplary TRF solution was the verification of our combination procedure. We used a number of multi-years solutions with station coordinates and velocities, e.g. input solutions submitted by several analysis centres for ITRF2000 computation (see <http://lareg.ensg.ign.fr/ITRF/ITRF2000/submissions.html>). Based on various criteria we performed a pre-selection of all these available solutions, and in addition we included some newer solutions containing more recent observations. According to our combination strategy (see Figure 1) several steps were performed (e.g. checking of individual solutions, removing constraints, reformatting from SINEX into DOGS format, reduction of stations with too few observations, epoch transformations for some of the solutions), before the individual normal equations (unconstrained) could be used for the intra-technique and/or inter-technique combination, and for the computation of the final combined TRF solution. A detailed description of the combination methodology, a summary of the results of this TRF computation and external comparisons (e.g. with ITRF2000) will be published soon.

Status and recommendations for the future

From our experiences regarding the analysis and combination of space geodetic observations we identified a number of deficiencies regarding current ITRF realizations, e.g.:
- One serious problem of the combination is the reduction of a-priori datum constraints which normally are included in the solutions.
- Systematic differences (biases) between different techniques and/or solutions are considered as one major limiting factor for the accuracy of the combined solution.
- The position time series reveal non-linear motions for a large number of sites, which are inconsistent with the conventional ITRF realization adapting cartesian coordinates and constant velocities for all IERS sites.
- Several stations are observed over short time intervals or in

early times of space geodesy (the eighties) only. Their inclusion does not only yield bad coordinates and velocities of the particular stations but might deform the network by systematic effects.

Recommendations for future ITRF realizations:

- To overcome the problems concerning the reduction of constraints, we recommend for future ITRF submissions, that unconstrained normal equations in addition to/or instead of solutions with variance-covariance matrices should be provided.
- Another important issue is to investigate the existing inconsistencies between different techniques and/or solutions regarding various aspects (e.g. modeling, parameterization, datum definition, analysis strategy) and to identify their origin.
- For the definition of the kinematic datum of the ITRF we propose to use kinematic models based on geodetic observations (e.g. APKIM) instead of geophysical models (e.g. NNR NUVEL-1A) to ensure that the no-net-rotation condition is more accurately fulfilled.
- The assumption of constant site velocities is not true in reality, since several geophysical phenomena may vary as a non-linear function of time (e.g. seismic or volcanic effects, deformations at plate boundary zones, local effects). Therefore, alternative – and probably more realistic – representations for the time evolution of the ITRS should be developed (e.g. time series of station positions).

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