RIGOROUS VLBI INTRA-TECHNIQUE COMBINATION FOR UPCOMING CRF REALIZATIONS

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ABSTRACT. The current realizations of the International Celestial Reference System (ICRS), the International Celestial Reference Frame 1 (ICRF1) and ICRF2, are based on solutions estimated by a single VLBI group. In contrast, the International Terrestrial Reference Frame (ITRF) is based on a multi-technique combination with contributions from different geodetic space techniques. These independent technique-specific solutions are again generated in intra-technique combinations of various analysis centers with all the benefits of combined solutions. To overcome the deficiencies of the past ICRF, one of the main objectives for the upcoming realizations of the fundamental frames should be a completely consistent and simultaneous determination of both frames. This involves inter- as well as intra-technique combinations. In multiple studies it has already been pointed out that the use of the intra-technique combination related to TRF and EOP estimations improves the stability and robustness of the results in comparison to individual solutions. This improvement should also be exploited for the CRF determination. In this work we focus on the consistency within the VLBI intra-technique combination. The main features and crucial steps of the developed CRF intra-technique combination strategy are explained and highlighted.

1. FEATURES OF THE EXISTING ICRF AND ITRF

Currently, the two existing fundamental frames, the International Celestial Reference Frame (ICRF) and the International Terrestrial Reference Frame (ITRF), are produced by different institutions and are based on various input data. The ICRF1 and ICRF2 (e.g., IERS 2009), both previous realizations of the ICRS, are single big monolithic solutions generated by the VLBI group at the NASA Goddard Space Flight Center (GSFC) using the Calc/Solve software package. Thus, the currently existing ICRF2, based on only one institution and one software package, is solely consistent to the GSFC specific TRF, which is aligned with the VLBI Terrestrial Reference Frame 2008 (VTRF2008) (Böckmann et al. 2010), and corresponding Earth Orientation Parameters (EOPs).

In contrast, the ITRF is based on contributions from four different geodetic space techniques [Global Navigation Satellite Systems (GNSS), Satellite Laser Ranging (SLR), Doppler Orbitography and Radio-positioning Integrated by Satellite (DORIS), Very Long Baseline Interferometry (VLBI)] and is computed in an inter-technique combination. This is done to benefit from the advantages of the individual solutions and to overcome technique-specific problems. Furthermore, these individual solutions are generated in an intra-technique combination of different analysis centers (ACs)(e.g., Böckmann et al. 2010).

Consequently, the current fundamental frames, the ICRF2 and the ITRF2008, as well as their related EOP series are not entirely consistent. To overcome this deficiency, both frames should be computed simultaneously and fully consistent in the upcoming realizations. Due to the fact that the EOPs are the direct link between both frames, this also comprises a simultaneous estimation of the EOP series.

In order to achieve these objectives and because of the fact that VLBI is the unique geodetic space technique which supplies source parameters for the CRF determination, it is necessary to focus on the consistency within the VLBI intra-technique combination. This is a first step towards a consistent realization of the upcoming ICRF3 and the respective ITRF version. At the present time, only the TRF and the related EOP series are regularly generated in a rigorous VLBI intra-technique combination by the International VLBI Service for Geodesy and Astrometry (IVS). By adding source positions to the rigorous VLBI intra-technique combination, the generation of a fully consistent VLBI output becomes possible. This innovation then links station coordinates, EOPs and source positions in a fully consistent way. The benefits of an intra-technique combination, which have already been shown for TRF and EOPs determinations in several studies (Böckmann 2010), will be exploited for the CRF combination as well.

2. COMBINATION STRATEGY

In order to guarantee that the contributions of the combination are not distored by any constraints before combining them, the rigorous combination is performed at the level of datum-free normal equation systems. Furthermore, it is ensured that the full variance-covariance information of all parameters and all input contributions is rigorously transferred. The underlying datum for the TRF and CRF can be applied during the combination, to ensure an identical datum for all input series in the whole process. Considering the goal, that we want to achieve consistency within the VLBI intra-technique combination, it is crucial that all contributing normal equation systems contain the whole set of parameters, including station coordinates, source positions and EOPs. For that reason, only four out of the official six IVS contributing ACs can presently be used for initial CRF investigations.

The proposed combination strategy can be divided into several sections illustrated in Fig. 1. First of all, VLBI solutions in the form of datum-free normal equation systems containing source positions, station coordinates and EOPs need to be stored together from all contributing ACs. The delivery and exchange of these solutions is based on the Solution Independent Exchange Format (SINEX). Since high precision geodetic VLBI has started in late 1979, over 5000 sessions were observered and analysed by each of the contributing ACs. These session-wise datum-free VLBI normal equation systems are combined in a first VLBI intra-technique combination step. The interim results are combined single session normal equation systems. In general, this intra-technique combination step leads to several substantial positive effects compared to using a single independent solution. The combination enables the analysis of differences, the uncovering of systematic effects and the detection of outliers. The stability and robustness of the final combined products is improved and the analyst's noise is reduced (Böckmann 2010). The combination step itself contains a couple of preprocessing steps, transformations and tests, to achieve sensible and reliable combined results.

Based on the combined single session normal equation systems, we are able to generate one monolithic datum-free normal equation,which is a completely consistent VLBI output, containing all CRF, EOP and TRF components. Even more important is that this combination strategy generates an ample scope of possibilities building a global VLBI output.

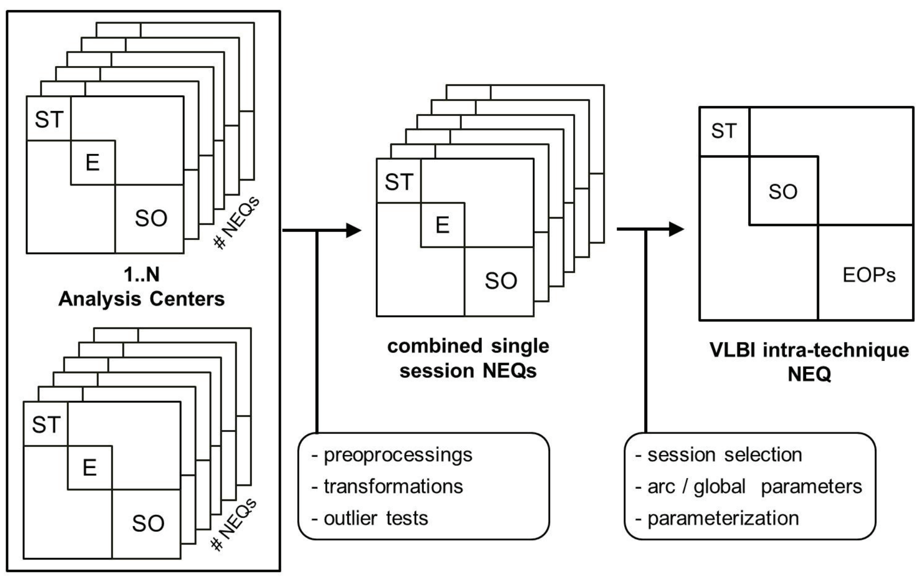

Figure 1: Combination strategy at the level of datum-free normal equations (NEQs). Parameter types: ST = station coordinates, E = EOPs, SO = source positions

Not all of the combined sessions are suitable for the determination of the desired parameters, therefore affected sessions can already be excluded in this intermediate step and will not influence the final products. Furthermore, the final parameterization of the CRF, TRF and EOP series can be freely chosen. Each parameter can be set up as an arc or a global parameter, i.e., being valid for either a single session only or the total time span, respectively. This offers the possibility to design the parameterization more appropriately than done in previous realizations of the fundamental frames. For example, the positions of special handling sources could be parameterized with continous piecewise linear functions or other suitable functions. In the previous realizations of the ITRS, station positions are represented with station coordinates and station velocities related to one explicit epoch. Considering the presented combination strategy it is imaginable and possible to represent motions of station coordinates with a different parameterization as well. Subsequently, the complete VLBI intra-technique normal equation system can contribute to the inter-technique combination. This enables an entirely consistent and simultaneous computation of the upcoming fundamental frames and their corresponding EOP series. It should be emphasized again that the full variance-covariance matrix of all sources is carried forward from each observing session and each AC to the final catalogue. The basic structure of the intra-technique combination strategy illustrated here is already realized in our software environment called BonnSolutionCombination (BoSC).

3. SUMMARY AND OUTLOOK

In this paper, a combination strategy for CRF determination has been presented. In order to generate a consistent CRF and TRF, investigations concerning the features and properties of a CRF combined from various VLBI solutions have to be made in upcoming studies. Individual CRFs based on solutions generated by different ACs are planned to be compared among themselves and to the official ICRF2. In this context, the impact of the additional data, which became available after the ICRF2 was published, can be examined as well. Based on comparisons between combined and individual CRFs we expect that a combined CRF provides improvements in terms of stability and robustness. Finally, we also plan to provide the mechanics for an inclusion of stand-alone catalogs, like K- and Ka-band reference frames, if full variance-covariance information is provided.

4. REFERENCES

Böckmann S., Artz T., Nothnagel A. (2010). VLBI terrestrial reference frame contributions to ITRF2008. Journal of Geodesy, 84, 201-219. doi: 10.1007/s00190-009-0357-7

Böckmann S., Artz T., Nothnagel A., Tesmer V. (2010). International VLBI Service for Geodesy and Astrometry: Earth orientation parameter combination methodology and quality of the combined products. Journal of Geophysical Research, 115, B04404, doi: 10.1029/2009JB006465

Böckmann S., Artz T., Nothnagel A., Tesmer V. (2007). Comparison and combination of consistent VLBI solutions. In: J. Böhm, A. Pany, H. Schuh (Eds.): Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting 2007, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Technische Universität Wien, ISSN 1811-8330, pp 82-87

Böhm J., Böhm S., Nilsson T., Pany A., Plank L., Spicakova H., Teke K. and Schuh H. (2012). The New Vienna VLBI Software VieVS. In: S. Kenyon, M.C. Pacino, U. Marti (Eds.): Proceedings of IAG Scientific Assembly 2009, International Association of Geodesy Symposia Series Vol. 136, pp 1007-1011, doi:10.1007/978-3-642-20338-1-126

IERS (2009). The second realization of the international celestial reference frame by very long baseline interferometry. In: A.L. Fey, D. Gordon, and C.S. Jacobs (Eds.): IERS Technical Note 35, presented on behalf of the IERS/IVS Working Group, Verlag des Bundesamtes fr Geodäsie und Kartographie, Frankfurt am Main