IVS Combination Center at BKG: ITRF2013 Preparations and Source Position Combination

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Abstract The IVS Combination Center at BKG is responsible for the IVS contribution to the ITRF2013. In preparation for the submission of the combined VLBI data, a detailed analysis of the individual input data of the IVS analysis centers have to be performed. Data format, station positions and EOP have to be investigated, e.g., for format correctness, systematic behavior, and outliers. For the first time, the IVS is advised to provide also combined source positions in the SINEX files. The source positions are estimated consistently with EOPs and the terrestrial reference frame (TRF). We present the generation of combined source position time series and a combined celestial reference frame as well as the combination approach, the current status of the analysis, and the combined results obtained so far for TRF, CRF, and EOPs.

Keywords VLBI, intra-technique combination, terrestrial reference frame, IVS

1 Introduction

Every few years the IERS ITRS Product Center initiates the generation of an inter-technique combined international terrestrial reference frame (ITRF), containing data from each of the four space-geodetic techniques, i.e., Satellite Laser Ranging (SLR), Global Navigation Satellite Systems (GNSS), Very Long Baseline Interferometry (VLBI), and Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS). The last ITRF (called ITRF2008) contains data until the end of 2008 and has been published in 2009 [3]. The upcoming ITRF will contain data up to 2013 and is called ITRF2013, which means five years of additional data are available compared to the ITRF2008. The contribution of the International VLBI Service for Geodesy and Astrometry (IVS) consists of a combined solution of individual submissions of Analysis Centers (AC). Individual solutions are based on datum free normal equations, which are transformed to equal epochs and equal a priori values for all parameters. Stacking the individual normal equations leads to a combined solution, which is then submitted to the IERS ITRS Product Center as official IVS contribution to the ITRF2013. Details on the combination process can be found in [1].

The call for participation has been sent out by the IERS ITRS Product Center in March 2013, proposing February 10, 2014 as submission deadline for all services. This deadline has been postponed by the IVS due to analysis software developments and preparation issues. Several ACs have already announced their participation, including some new institutions with their own developed analysis software, which implies a more heterogeneous combined solution. Overall, about ten contributions are expected for the IVS combination, which means a total amount of $\sim$60,000 SINEX files. The preparation for the ITRF2013 started already at the end of 2013 with several discussions on submission instructions, axis offsets, EOP parameterization, and source position handling. First test files have been made available in the IVS Data Center on February 10, 2014 (go to ftp://ivs.bkg.bund.de/pub/vlbi/ITRF2013/daily_sinex/). Other submissions have been submitted since that time or are expected to follow.

Federal Agency for Cartography and Geodesy

Table 1 Institutions and software packages contributing to the ITRF2013 effort.

Abbreviation	Institution	Software	Contribution to operational products
AUS	Geoscience Australia, Australia	Occam	no
BKG	Federal Agency for Cartography and Geodesy, Germany	Calc/Solve	yes
DGFI	German Geodetic Research Institute, Germany	Occam	yes
GFZ	German Research Center for Geosciences	VieVS	no
GSFC	Goddard Space Flight Center, USA	Calc/Solve	yes
IAA	Institute of Applied Astrometry, Russia	Quasar	yes
NMA	Norwegian Mapping Authority, Norway	Geosat	no
OPAR	Observatory of Paris, France	Calc/Solve	yes
SHAO	Shanghai Observatory, China	Calc/Solve	no
USNO	US Naval Observatory, USA	Calc/Solve	yes
VIE	Vienna University of Technology, Austria	VieVS	no

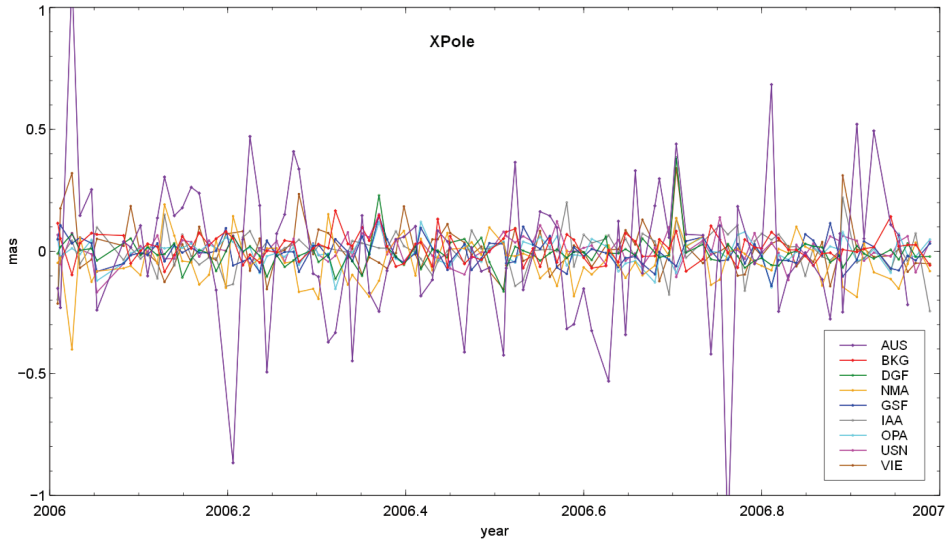

Fig. 1 X-Pole for the year 2006 estimated by different ACs w.r.t. the IVS combination.

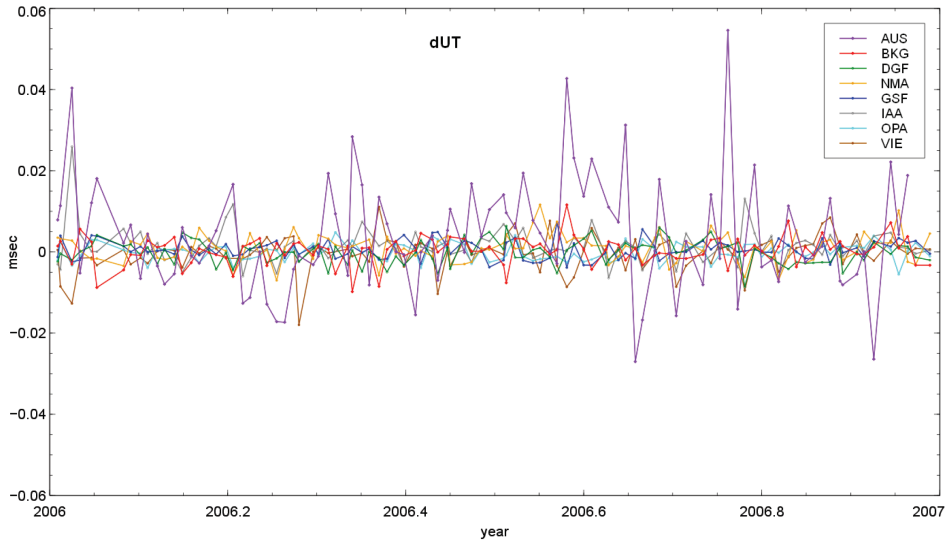

Fig. 2 dUT for the year 2006 estimated by different ACs w.r.t. the IVS combination.

2 Data

The data comprises 24-hour VLBI sessions until the end of 2013. The analyzed sessions are submitted in SINEX file format[1] to the IVS data center. In general, the ACs are free to decide which sessions are analyzed back to the beginning of VLBI observations in the early 1980s. The overall combination process is close to the operational quarterly combination. Parameters are station coordinates and Earth orientation parameters (EOPs). Source positions are left out, but further investigations are foreseen for the post-ITRF2013 era. A robust outlier test for station coordinates and EOPs is applied based on Least-Median-of-Squares method and a group-wise software package variance-component estimation (VCE) is applied as described in [2]. As of March 2013 the following software packages are expected to contribute to the IVS combination: Calc/Solve, QUASAR, OCCAM (LSM[2], LSC[3]), GEOSAT, and VieVS.

Also some further institutions announced their participation, i.e., AUS (Australia), NMA (Norway), and VIE (Austria) with whom iterative development of format issues, parameterization, and modeling (among other things) have been discussed within the last weeks. Table 1 gives an overview of the expected contributions and software packages.

3 Analysis

Some test combination series have been generated in order to set up the combination software and the databases for the storage of the estimates which will be used for quality analysis of the submitted data later on. The general IVS submission is behind ITRF schedule; not all ACs have submitted data yet. Comparisons are thus performed using test series provided in advance and/or sessions provided in the IVS Data Center which are used for operational rapid and quarterly combination, but which are not generated for ITRF2013 combination explicitly.

Figure 1 shows the X-Pole for sessions in 2006 by different ACs w.r.t. the combined solution. The plot does not show a systematic behavior for any of the ACs, and the solutions are nicely scattered around zero. One of the ACs (i.e., AUS) still shows a larger amplitude, where the AC is already working on an improvement. In Figure 2 dUT1 is shown for the same time span and the same data source. Similar to Figure 1 no systematics can be seen. At the time of writing (March 2014) only a common data set for one year has been provided by the ACs and not every AC which announced their participation provided test data for comparisons. For conclusive studies of EOP and station coordinates concerning systematic behavior, offsets, or drifts in the time series more data have to be considered which will be submitted by the ACs within the upcoming weeks.

In Table 2 the weighted root mean square (wrms) over the one-year time span w.r.t. the combined solution is shown. This value is computed by summing up the weighted residuals after the combination and represents a quality indicator for the individual contribution within and w.r.t. the combined solution.

Table 2 WRMS of the residuals for EOPs for 2006.

	X_P [μas]	Y_P [μas]	dUT [μs]	X_P Rate [μas/day]	Y_P Rate [μas/day]	LOD [μs/day]	dX [μas]	dY [μas]
AUS	183	207	9	386	376	84	N/A	N/A
BKG	46	49	3	171	140	7	47	48
DGFI	30	40	2	136	135	6	N/A	N/A
GSFC	44	36	2	124	112	5	29	31
IAA	58	59	3	190	206	12	50	41
NMA	64	68	3	219	214	26	50	44
OPAR	42	39	2	120	104	4	26	32
USNO	49	68	7	183	157	8	44	55
VIE	58	51	3	195	172	9	63	58

Generally, the table shows a good agreement between the ACs and good results for the test data for one year. Comparisons between the contributed solutions over the whole time span of $\sim$30 years of data and all contributions will follow as soon as the submission for ITRF contributions is completed.

The individual weighting of the contributions is done by a variance component estimation (VCE). As in the operational rapid and quarterly combinations (http://ccivs.bkg.bund.de/) a number of ACs are using the same software package (highlighted in red (gray) in Table 2) a group-wise VCE was introduced which forms groups of software packages. Contrary to a VCE

[1] http://www.iers.org/

[2] LSM = Least Squares Method

[3] LSC = Least Squares Collocation Method

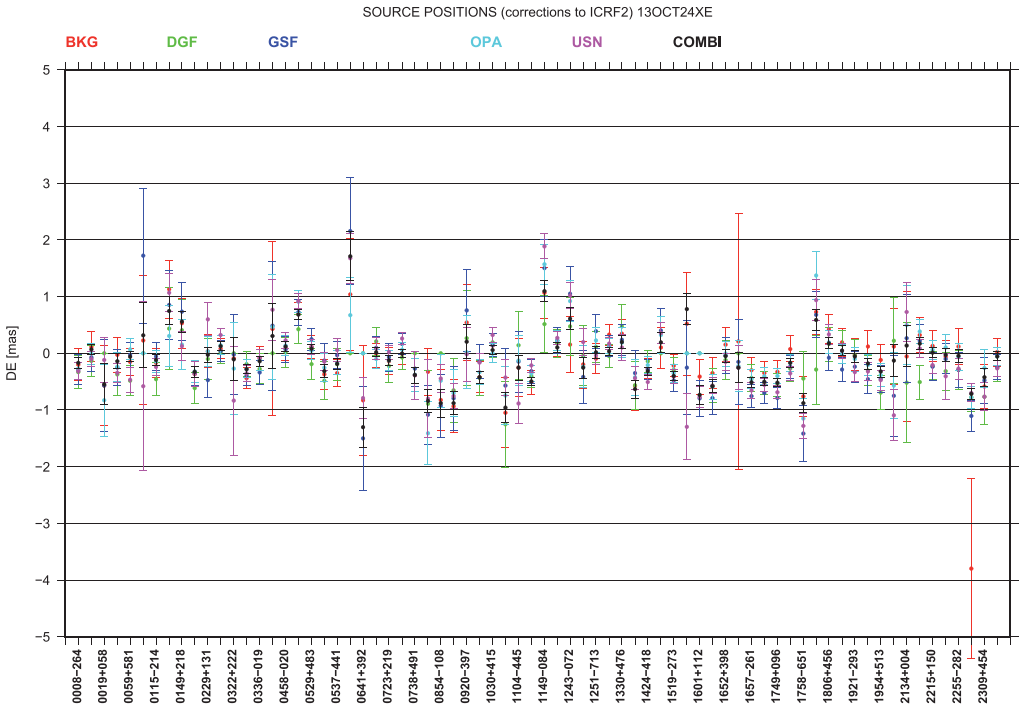

Fig. 3 Estimated source positions (declination) for session 13OCT24XE (R4608).

where each AC is represented by one group, this approach compensates for a disproportional impact of one software package. Meanwhile, eleven ACs (six ACs are currently contributing to the operational rapid and quarterly combination) announced their participation for the IVS contribution with different software packages. Using all the contributions (once they are all submitted) the above mentioned effect can be investigated using a larger number of contributions and a broader variety of software packages. This investigation and other comparisons will be performed when all institutions have submitted their contributions for the ITRF2013 to the IVS Data Center.

Combination of Source Positions

Source positions are provided by most of the IVS Analysis Centers. Initially, the combination and submission of source positions was foreseen for the ITRF2013. After some discussions within the IVS it was decided not to include them in the IVS submission for ITRF2013, but to perform further investigations after the calculations for the ITRF2013 have been finished. Nevertheless, combination routines for source positions have been set up and tested for a limited amount of data. First single sessions have already been combined and a global solution for the celestial reference frame (CRF) was generated. The results are promising. As an example, Figure 3 shows the results of source positions for session 13OCT24XE (R4608) for individual ACs and the combined solution w.r.t. the ICRF2 positions (cf. http://hpiers.obspm.fr/icrs-pc/). The differences are in a range of ± 0.5 to 1 mas, with some possible outliers for single sources only.

Figure 4 shows the result of a global source solution (CRF) generated with the CONT11[4] campaign data. The combined solution is the result of stacking all combined normal equations for the individual sessions. The comparison of the combined CRF and the source positions given in the ICRF2 shows differences in the order of ± 0.2 mas in right ascension (RA) and declination (DE).

Further investigations of source position combination are foreseen after the IVS submission for the ITRF2013 was completed.

[4] http://ivs.nict.go.jp/mirror/program/cont11/

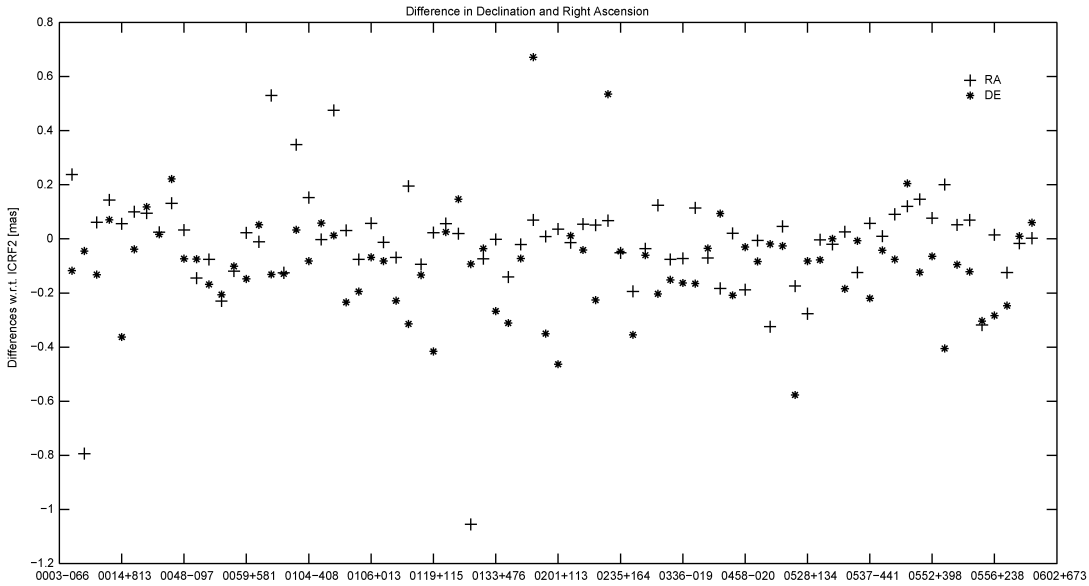

Fig. 4 Source positions w.r.t. ICRF2 estimated from the CONT11 data as a combination of 5 Analysis Center contributions.

4 Summary and Conclusions

For the ITRF2013 preparations test data are available, but not even half of the expected submissions have been submitted to the IVS data center. The data that have been tested for the new institutions look promising. Contributions from manifold software packages and many contributors are expected, which helps to expand the heterogeneity of the combined solution. First contributions have been submitted to the IVS data center. A first combined IVS solution including all contributions that were promised is expected to be ready in May 2014 (status quo April 2014).

Concerning the source position combination, an inclusion of source positions into the ITRF combination has originally been envisaged for ITRF2013, but further investigations on source position analysis and combination were postponed by the IVS to the post-ITRF2013 era. Nevertheless, the combination software was already expanded so that the inclusion of source positions has been integrated in the combination routines. First results are looking promising both for the single session combination and for the global CRF solution.

References

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