The BKG/IGGB VLBI Analysis Center

Volkmar Thorandt, Axel Nothnagel, Gerald Engelhardt, Dieter Ullrich, Thomas Artz, S. Tesmer née Böckmann, Judith Pietzner

Abstract

In 2010, the activities of the BKG/IGGB VLBI Analysis Center, as in previous years, consisted of routine computations of Earth orientation parameter (EOP) time series and of a number of research topics in geodetic VLBI. The VLBI group at BKG continued its regular submissions of time series of tropospheric parameters and the generation of daily SINEX (Solution INdependent EXchange format) files. Quarterly updated solutions have been computed to produce terrestrial reference frame (TRF) and celestial reference frame (CRF) realizations. Routine computations of the UT1–UTC Intensive observations include all sessions of the Kokee–Wettzell and Tsukuba–Wettzell baselines and the networks Kokee–Svetloe–Wettzell and Ny-Ålesund–Tsukuba–Wettzell. At IGGB, the emphasis has been placed on individual research topics.

1. General Information

The BKG/IGGB VLBI Analysis Center has been established jointly by the analysis groups of the Federal Agency for Cartography and Geodesy (BKG), Leipzig, and the Institute of Geodesy and Geoinformation of the University of Bonn (IGGB). Both institutions cooperate intensely in the field of geodetic VLBI. The responsibilities include both data analysis for generating IVS products and special investigations with the goal of increasing accuracy and reliability. BKG is responsible for the computation of time series of EOP and tropospheric parameters, for the generation of SINEX files for 24-hour VLBI sessions and 1-hour Intensive sessions, and for the generation of quarterly updated global solutions for TRF and CRF realizations. Besides data analysis, the BKG group is also responsible for writing schedules for the Tsukuba-Wettzell INT2 UT1-UTC observing sessions. IGGB continues to host the office of the IVS Analysis Coordinator and carries out special investigations within the technique of geodetic and astrometric VLBI. Details of the research topics of IGGB are listed in Section 3.

2. Data Analysis at BKG

At BKG, the Mark 5 VLBI data analysis software system Calc/Solve, release 2010.05.21 [1], has been used for VLBI data processing. It is running on a Linux operating system. The software is now able to use the IAU2006 Nutation/Precession model. As in the previous releases the Vienna Mapping Function (VMF1) has been implemented in a separate Solve version. This modified version was used for all data analysis. The VMF1 data were downloaded daily from the server of the Vienna University of Technology. Additionally, the technological software environment for Calc/Solve has been refined to link the Data Center management with the pre- and post-interactive parts of the EOP series production and to monitor all Analysis and Data Center activities.

- **Processing of correlator output**
  The BKG group continued the generation of calibrated databases for the sessions correlated at the MPIfR/BKG Mark 5 Astro/Geo Correlator at Bonn (e.g., EURO, OHIG, and T2) and submitted them to the IVS Data Centers.

- **Scheduling**
  BKG continued scheduling the INT2 Intensive sessions, which are observed on the baselines TSUKUBA-WETTZELL, KASHIMA-WETTZELL, KASHIMA-WESTFORD, and TSUKUBA-WESTFORD. Altogether 92 schedule files were created in 2010.

- **BKG EOP time series**
  The old BKG EOP time series bkg00012 was replaced by the new bkg00013. One main difference to the former solution is the new a priori set of coordinates of the second realization of the International Celestial Reference Frame (ICRF2) [2]. Further the estimation of the nutation parameters in this series is based on partial derivatives of X,Y-nutation components with respect to IAU2000A/2006 precession and nutation models. Because of a big earthquake in the region of the VLBI station TIGOCONC in Chile with station displacements of about 3 meters, the modeling of this station was changed from globally estimated station coordinates to locally estimated coordinates in all post-quake sessions.

  Each time after the preprocessing of any new VLBI session (correlator output database version 1), a new global solution with 24-hour sessions since 1984 was computed, and the EOP time series bkg00013 was extracted. Altogether 4097 sessions were processed. The main parameter types in this solution are globally estimated station coordinates and velocities together with radio source positions. The datum definition was realized by applying no-net-rotation and no-net-translation conditions for 26 selected station positions and velocities with respect to VTRF2008a and a no-net-rotation condition for 295 defining sources with respect to ICRF2. The station coordinates of the telescopes AIRA (Japan), CHICHI10 (Japan), CTVASTJ (Canada), DSS13 (USA), HOBART12 (Australia), PT_REYES (USA), SEST (Chile), SINTOTU3 (Japan), TIGOCONC (Chile), WIDE85_3 (USA), VERAISGK (Japan), VERAMZSW (Japan), and YEBES40M (Spain) were estimated as local parameters in each session.

  The UT1-UTC Intensive time series bkgint08 was replaced by bkgint09. The series bkgint09 was generated with fixed TRF (VTRF2008a) and fixed ICRF2. The estimated parameter types were only UT1-TAI, station clock, and zenith troposphere. Observations of the two baselines KOKEE-WETTZELL and TSUKUBA-WETTZELL and also of the networks KOKEE-SVETLOE-WETTZELL and NYALES20-TSUKUBA-WETTZELL were processed regularly. The analysis of the e-VLBI experiments each week on Mondays could be finished almost always on the same day. Delays of maximal one day appeared because of problems in data transfer. The lack of observations due to maintenance and repair work at WETTZELL could be compensated by observations with WESTFORD and Ny-Ålesund. A total of 3476 UT1 Intensive sessions were analyzed for the period from 1999.01.01 to 2010.12.31.

- **Quarterly updated solutions for submission to IVS**
  In 2010, one quarterly updated solution was computed for the IVS products TRF and CRF. There are no differences in the solution strategy compared to the continuously computed EOP time series bkg00013. The results of the radio source positions were submitted to IVS in IERS format. The TRF solution is available in SINEX format, version 2.1, and includes station coordinates, station velocities, and radio source coordinates together with the covariance matrix, information about constraints, and the decomposed normal matrix and vector.

- **Tropospheric parameters**

The VLBI group of BKG continued regular submissions of long time series of tropospheric parameters to the IVS (wet and total zenith delays and horizontal gradients) for all VLBI sessions since 1984. The tropospheric parameters were extracted from the standard global solution bkg00013 and transformed into SINEX format.

- **Daily SINEX files**
  The VLBI group of BKG also continued regular submissions of daily SINEX files for all available 24-hour sessions for the IVS combined products and for the IVS time series of baseline lengths. In addition to the global solutions, independent session solutions with the new models mentioned above were computed for the station coordinates, radio source coordinates, and EOP parameters including the X,Y-nutation parameters. The a priori datum for TRF is defined by the VTRF2008a, and ICRF2 is used for the a priori CRF information.
- **SINEX files for Intensive sessions**
  The parameter types are station coordinates, pole coordinates and their rates, and UT1-TAI and its rate. But only the normal equations stored in the SINEX files are important for further combination with other space geodetic techniques.

3. Research Topics at IGGB

- **Correlations within the IVS combination process**
  As the contributions of each Analysis Center (AC) to the official IVS combined products are derived from virtually the same set of original observations, correlations between the contributions are expected. So far, this topic has been completely neglected in any intra-technique combination approach. In a study [3], the observation equations of two ACs (BKG and IGGB) have been used directly for the combination (in contrast to using normal equation systems, NEQs). With this approach, the level of correlations has been determined, and the influence of neglecting the correlations on the estimated combined parameters as well as their formal errors have been investigated. Based on CONT02 observations, it turned out that a realistic level of correlations between the two contributions lies between 0.5 and 0.7, which is much less than expected.
- **Determination of sub-daily tidal ERP models**
  The IERS model for tidal Earth Rotation Parameter (ERP) variations with periods around one day and below as given in the IERS Conventions [4] does not describe all effects that are measured by VLBI. An empirical model has been estimated from VLBI observations applying a new approach based on the transformation of NEQs [5]. Furthermore, the general reliability and stability of VLBI-derived sub-daily ERP has been investigated [6].

  Furthermore, the approach of estimating a sub-daily tidal ERP model applying the transformation of NEQs has been used to determine a combined model based on homogeneously reprocessed GPS and VLBI NEQs. This combination also allows to determine long term time series of hourly spaced ERPs. It turned out that the combined time series can be estimated almost without any constraints as geometric instabilities of the techniques are cross-wise compensated and the stochastic noise is reduced which is the very purpose of combinations.
- **Gravitational deformation of the Effelsberg radio telescope**
  Radio telescopes are subject to varying gravitational effects when tilted in different ele-

vation angles for observations of extra-terrestrial objects. The Effelsberg radio telescope's paraboloid was subject to a novel type of survey being carried out with a total station. It was mounted head-down close to the sub-reflector of the telescope to determine the paraboloid deformations through coordination of discrete points on the surface. The main reflector of the telescope is subject to displacements of individual points of up to 54 mm, while the focal length changes by about 13 mm when the telescope is tilted from 90° to 7° pointing elevation.

4. Personnel

Table 1. Personnel at BKG/IGGB Analysis Center

Thomas Artz	IGGB	+49-228-733563	thomas.artz@uni-bonn.de
Gerald Engelhardt	BKG	+49-341-5634438	gerald.engelhardt@bkg.bund.de
Axel Nothnagel	IGGB	+49-228-733574	nothnagel@uni-bonn.de
Judith Pietzner	IGGB	+49-228-733565	judith.pietzner@igg.uni-bonn.de
Sarah Tesmer née Böckmann	IGGB	+49-228-733563	boeckmann@uni-bonn.de (until Dec. 15, 2010)
Volkmar Thorandt	BKG	+49-341-5634285	volkmar.thorandt@bkg.bund.de
Dieter Ullrich	BKG	+49-341-5634328	dieter.ullrich@bkg.bund.de
Reiner Wojdziak	BKG	+49-341-5634286	reiner.wojdziak@bkg.bund.de

References

[1] GSFC, NASA (2010): Release of Mark 5 VLBI Analysis Software Calc/Solve from May 21, 2010 (Web reference: http://gemini.gsfc.nasa.gov/solve).

[2] Ma, C. et al. (2009) IERS Technical Note No. 35: The Second Realization of the International Celestial Reference Frame by Very Long Baseline Interferometry; Presented on behalf of the IERS/IVS Working Group, edited by Alan L. Fey, David Gordon, Christopher S. Jacobs.

[3] Böckmann, S., T. Artz and A. Nothnagel (2010) Correlations between the contributions of individual IVS analysis centers, In: Behrend, D. and K. D. Baver (Eds.), IVS 2010 General Meeting Proceedings, NASA/CP-2010-215864, 222-226, 2010.

[4] McCarthy, D. and G. Petit (2004) IERS Conventions (2003), IERS Technical Note 32, Verlag des Bundesamtes für Kartographie und Geodäsie, Frankfurt am Main, (available electronically at http://www.iers.org/IERS/EN/Publications/TechnicalNotes/tn32.html).

[5] Artz, T., S. Böckmann and A. Nothnagel (2011) Assessment of Periodic Sub-diurnal Earth Orientation Parameter Variations at Tidal Frequencies via Transformation of VLBI Normal Equation Systems, submitted to J Geod.

[6] Artz, T., L. Bernhard, A. Nothnagel, P. Steigenberger and S. Tesmer (2011) A Rigorously Combined Sub-daily Earth Rotation Model from GPS and VLBI Observations, submitted to J Geophys Res.

[7] Artz, T., S. Böckmann, L. Jensen, A. Nothnagel and P. Steigenberger (2010) Reliability and Stability of VLBI-derived Sub-Daily EOP Models, In: Behrend, D. and K. D. Baver (Eds.), IVS 2010 General Meeting Proceedings, NASA/CP-2010-215864, 355-359, 2010.