BKG VLBI Analysis Center

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Abstract In 2019 and 2020, the activities of the BKG VLBI Analysis Center, as in previous years, consisted mainly of routine computations of Earth orientation parameter (EOP) time series. 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. The analysis of *Intensive* sessions for UT1–UTC estimation was also continued. All solutions from 2019 are based on the Calc/Solve software, release 2014.02.21 [2], using the old Mark III database format. At the same time, the new geodetic VLBI software νSolve [4] was also used for the analysis of sessions in the new vgosDB data format. At the end of 2019, the new Calc/Solve software, release 2019.11.21 [3], was successfully installed and tested to generate input for the ITRF2020 VLBI combination solution.

1 General Information

The Federal Agency for Cartography and Geodesy (BKG) maintains a VLBI Analysis Center for the generation of products defined by the International VLBI Service for Geodesy and Astrometry (IVS). This includes data analysis for generating IVS products and special investigations with the goal of increasing accuracy and reliability.

The BKG VLBI Analysis Center is responsible for the computation of time series of EOP and tro-

pospheric parameters, for the generation of SINEX files for 24-hour VLBI sessions and one-hour *Intensive* sessions, and for the generation of quarterly updated global solutions for TRF and CRF realizations. Besides data analysis, the BKG VLBI group was also responsible for writing schedules for the *Int2* UT1–UTC observing sessions in 2019.

2 Data Analysis at BKG

At BKG, the Mark 5 VLBI data analysis software system Calc/Solve, release 2014.02.21 [2], has been used for VLBI data processing in the old chain of Mark3 databases. It is running on a Linux operating system. At the same time, data analysis of sessions in the new vgosDB format was carried out with the new interactive geodetic VLBI software νSolve [4].

Furthermore, the new Calc/Solve software, release 2019.11.21 [3], has been used since the end of 2019 after its successful installation and testing. All old Mark3 databases could thus be transformed into the new vgosDB data format. This new software also allows the use of new models in the VLBI evaluation, e.g., galactic aberration and gravitational deformation of VLBI antennas or the generation of so-called tropospheric path delay (TRP) files derived from the Vienna Mapping Function (VMF3) data. The TRP files contain external information about the troposphere on a scan-by-scan basis, specifically the a priori delay, dry and wet mapping functions, and gradient mapping functions. The BKG VLBI group uses TRP files to input data related to VMF3. The VMF3 data were downloaded daily from the server of the Vienna University of Technology.

On the basis of the new software, it was possible to further develop the new processing chain of vgos databases for the generation of IVS products in the reporting period. The technological connection between the VLBI data in the Data Center, preliminary evaluation with νSolve, product-based evaluation with Calc/Solve, and product generation for the IVS Data Centers is realized by Python scripts.

- **Processing of Correlator Output**
  The BKG group continued the generation of calibrated databases in the new vgosDB format for the sessions correlated at the Max Planck Institute for Radio Astronomy (MPIfR)/BKG Astro/Geo Correlator at Bonn (e.g., EURO, OHIG, and T2) and submitted them to the IVS Data Centers.

- **Scheduling**
  In cooperation with the Institute of Geodesy and Geoinformation of the University of Bonn (IGGB), BKG continued scheduling the Int2 *Intensive* sessions, which are mostly observed on the ISHIOKA–WETTZELL baseline. In 2019, a total of 102 schedule files were created. In 2020, this work was discontinued due to the establishment of the IVS VLBI Operation Center Wettzell, which took over this function.

- **BKG EOP Time Series**
  The BKG EOP time series bkg00014 was continued [1] but only for the R4 session series, available in the old MK3 data format. This old EOP time series based on MK3 databases was stopped at the end of 2020. It was replaced by the new bkg2020a series, based on sessions in the new vgosDB data format. The main difference to the previous solution is the use of new models for, for instance, galactic aberration, mean pole tides, gravitational deformation, and high-frequency EOP, which are also used for the realization of ITRF2020. Further, the new VLBI stations NYALE13S in Norway and SVERT13V in Russia were included successfully in the data processing.

  Each time after the preprocessing of any new VLBI session (correlator output vgosDB database version 1), a new global solution with 24-hour sessions since 1984 was computed, and the EOP time series bkg2020a was extracted. Altogether, 5,785 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 25 selected station positions and velocities with respect to ITRF2014 and a no-net-rotation condition for 303 defining sources with respect to ICRF3. The station coordinates of the telescopes AGGO (Argentina), AIRA (Japan), CHICHI10 (Japan), CTVASTJ (Canada), DSS13 (USA), DSS34 (Australia), DSS36 (Australia), ISHIOKA (Japan), KASHIM11 (Japan), KASHIM34 (Japan), KOGANEI (Japan), NYALE13S (Norway), PT_REYES (USA), RAEGSMAR (Azores), RAEGYEB (Spain), SEST (Chile), SINTOTU3 (Japan), SVERT13V (Russia), TIANMA65 (China), TIDBIN64 (Australia), TIGOCONC (Chile), TSUKUB32 (Japan), UCHINOUR (Japan), VERAISGK (Japan), VERAMZSW (Japan), WARK30M (New Zealand), WETTZ13N (Germany), WIDE85_3 (USA), and YEBES40M (Spain) were estimated as local parameters in each session.

- **BKG UT1 *Intensive* Time Series**
  The analysis of the UT1–UTC *Intensive* time series bkgint14 was continued. But this old time series based on MK3 databases was stopped at the end of August 2020 and replaced by the new bkg2020a series, which is based on *Intensive* sessions in the new vgosDB data format. The main difference to the old series is again the use of the new models and the new a priori TRF and CRF.

  The series bkg2020a was generated with fixed TRF (ITRF2014) and fixed ICRF3. The a priori EOP were taken from final USNO series [5]. The estimated parameter types were only UT1–TAI, station clock, and zenith troposphere. A total of 1,198 UT1 *Intensive* sessions were analyzed for the period from 2018.01.02 to 2020.12.30.

- **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, which were still available in the old MK3 data format. This old series, bkg00014, based on MK3 databases was stopped at the end of 2020. It was replaced by the new bkg2020a series, which is based on sessions in the new vgosDB data format. The tropospheric parameters were extracted from the standard global solution bkg2020a and trans-

formed into tropospheric SINEX format for IVS submission.

- **Daily SINEX Files**

  The VLBI group of BKG also continued regular submissions of daily SINEX files (bkg2014a) for all available 24-hour sessions in the old MK3 data format for the IVS combined products and for the IVS time series of baseline lengths. This solution was stopped in mid-2020 and replaced by a solution, bkg2020a, based on sessions in the new vgosDB data format and new parameterization aligned with ITRF2020 requirements.

  The new 24-hour session solutions (bkg2020a) include estimates of station coordinates, radio source coordinates, and EOP including the X,Y-nutation parameters. The a priori datum for TRF is defined by the ITRF2014, and ICRF3 is used for the a priori CRF information.

- **SINEX Files for *Intensive* Sessions**

  The generation of SINEX files for all *Intensive* sessions (bkg2014a) in the old MK3 data format continued until mid-2020. This solution was replaced by a new set of SINEX files (bkg2020a) based on *Intensive* sessions in the new vgosDB data format and new models and a priori TRF (ITRF2014) and CRF (ICRF3) in the parameter estimation.

  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 intra-technique combination or combination with other space geodetic techniques.

- **Contribution to ITRF2020**

  The BKG Analysis Center submitted 6,201 SINEX files for 24-hour sessions to IVS as input to a combined VLBI solution for ITRF2020. There is no difference in the parameterization to the IVS product daily SINEX files bkg2020a. The contribution from BKG to ITRF2020 also includes 38 SINEX files that were generated from the analysis of broadband vgosDB databases.

3 Personnel

Table 1 Personnel at the BKG Analysis Center.

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2. GSFC, NASA (2014): Release of Mark 5 VLBI Analysis Software Calc/Solve from February 21, 2014 (Web reference: https://ivscc.gsfc.nasa.gov/IVS_AC/IVS-AC_contact.htm)
3. GSFC, NASA (2019): Release of Mark 5 VLBI Analysis Software Calc/Solve from November 21, 2019 (Web reference: https://ivscc.gsfc.nasa.gov/IVS-AC_contact.htm)
4. GSFC, NASA (2020): Release of *v*Solve 0.7.0 from March 5, 2020 (Web reference: https://sourceforge.net/projects/nusolve/)
5. USNO (2020): Earth orientation parameter series from finals USNO series 2020 (Web reference: https://cddis.nasa.gov/archive/vlbi/gsfc/ancillary/solve_apriori/usno_finals.erp)