BKG VLBI Analysis Center

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Abstract In 2021 and 2022, the activities of the BKG VLBI Analysis Center, as in previous years, consisted mainly of routine VLBI analysis for IVS. Our solutions are computed with the geodetic VLBI software νSolve [5] for the analysis of sessions in the vgosDB data format and the Calc/Solve software, release 2019.11.21, revision date 2020.01.23. In 2021 the generation of the BKG AC contribution for ITRF2020 was completed.

We are also supporting new software developments for the Bernese GNSS Software, in order to process VLBI data of vgosDB version 4.

1 General Information

The German Federal Agency for Cartography and Geodesy (BKG) maintains the VLBI Analysis Center with the status of an operational Analysis Center as defined by the International VLBI Service for Geodesy and Astrometry (IVS).

The BKG VLBI Analysis Center is responsible for the computations of Earth orientation parameter (EOP) EOP-S time series derived from 24-hour sessions and EOP-I *Intensive* sessions as well as corresponding (Solution INdependent EXchange format) SINEX products. The VLBI group at BKG continues regular submissions of the tropospheric parameter time series. The quarterly updated solutions were obtained as well in both years to produce terrestrial reference frame (TRF) and celestial reference frame (CRF) products.

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It is worth highlighting that the BKG AC makes an effort to maintain the analysis workflow starting with the computed group delays given in version 1 of the wrapper file of the vgosDB data format.

The processing chain of VGOS databases for generating IVS products in the reporting period was further developed and refined. The technical VLBI data handling supports routine acquisition from the Data Center, preliminary evaluation with νSolve routines, product-based evaluation with Calc/Solve, and final preparation of the products for IVS, which includes the products' delivery to the BKG Data Center.

2 Data Analysis at BKG

The initial step of the data analysis is carried out with the interactive geodetic VLBI software νSolve [5]. The Mark 5 VLBI data analysis software system Calc/Solve, release 2019.11.21 [4], is utilized for the processing of the so-called level 4 of the vgosDB provided by νSolve to build the IVS products.

- **Processing of version 1 of the wrapper file of the vgosDB data format**
  The BKG group continued the processing of the calibrated databases in the vgosDB format starting with the version 1 wrapper file for all of the sessions in the master files. The vgosDb is filled, then, with the required reductions to generate the version 2 and 3 wrapper files by means of νSolve routines vgosDbCalc and vgosDbProcLogs. The corrections for the ambiguities and ionosphere are computed independently with νSolve [5], where it is required, in the first step of the data analysis. In the second step, the minimum parameteriza-

tion is applied in *v*Solve to remove the outliers, and the final results are stored as the version 4 wrapper file. We note that ionospheric corrections are taken into account in available group delays for the VGOS observations, where the ambiguities resolution is also facilitated by broadband data advantage. The obtained level 4 data is available at the designated area of the BKG DC (see ftp://ivs.bkg.bund.de/pub/vlbi/ivsdata/vgosdb_bkg/).

- **Responsibility of the BKG AC to deliver level 4 of the vgosDB**
  The analyzed sessions (level 4 of the vgosDB) correlated at the Max Planck Institute for Radio Astronomy (MPIfR)/BKG Astro/Geo Correlator at Bonn, namely OHIG and T2, are delivered to the IVS Data Centers to fulfill the BKG AC responsibility as assigned according to the master file.
- **BKG EOP time series**
  The BKG EOP time series bkg2020a is supported as described [1], which data set is extended by all available broadband VGOS sessions according to the master file. The station coordinates of stations DSS13 (USA), ISHIOKA (Japan), RAEGYEB (Spain), TIANMA65 (China), and WETTZ13N (Germany) were determined now as global parameters due to the collected observation period longer than three years. A number of new VLBI stations were included in the data processing: DSS26 (USA) and DSS56 (Spain) as well as the new VGOS stations GGAO12M (USA), KOKEE12M (USA), MACGO12M (USA), ONSA13NE (Sweden), ONSA13SW (Sweden), and WETTZ13S (Germany). Each time after preprocessing of a new VLBI session, a new global solution including over 6,300 24-hour sessions since 1984 was computed, and the operational EOP time series bkg2020a was built. In this solution the station coordinates and velocities were globally estimated, as well as the source positions and EOP. The datum definition was realized by applying no-net-rotation and no-net-translation conditions for 46 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), DSS26 (USA), DSS34 (Australia), DSS36 (Australia), DSS56 (Spain), KASHIM11 (Japan), KASHIM34 (Japan), KOGANEI (Japan), NYALE13S (Norway), OHIGGINS (Antarctica), PT_REYES (USA), RAEGSMAR (Azores), SEST (Chile), SINTOTU3 (Japan), SVERT13V (Russia), TIDBIN64 (Australia), TIGOCONC (Chile), TSUKUB32 (Japan), UCHINOUR (Japan), VERAISGK (Japan), VERAMZSW (Japan), WARK30M (New Zealand), WIDE85_3 (USA), and YEBES40M (Spain) were estimated as local parameters in each session.

  The next generation series bkg2022a was introduced in 2022 as soon as ITRF2020 was released. The new time series is supported along with the operational bkg2020a series. The main difference with respect to the existing solution bkg2020a is the use of the newly available ITRF2020 for the a priori station coordinates and velocities as well as the associated post-seismic deformation model. The bkg2022a series is to become the operational EOP and SINEX product, when the IVS announces the switch to ITRF2020.
- **BKG UT1** *Intensive* **time series**
  The analysis of the UT1-UTC *Intensive* time series bkg2020a was continued. The time series bkg2020a is generated with the station positions fixed to ITRF2014 and source positions fixed to ICRF3. The a priori EOP are taken from the USNO finals time series [6]. The estimated parameters are UT1-TAI, station clocks, and zenith wet delay. In 2022, a new UT1-UTC *Intensive* time series bkg2022a was created similar to the EOP-S products, where the only difference with respect to the existing solution bkg2020a is the use of the new a priori ITRF2020.

  A total of 1,255 *Intensive* sessions were analyzed for the period from 2021.01.03 to 2022.12.31.
- **Quarterly updated solutions**
  In 2021, the quarterly updated solutions were computed for the IVS products TRF and CRF. There are no differences in the solution computation strategy compared to the continuously obtained EOP time series bkg2020a. In 2022, the quarterly solutions were calculated also according to the description of the time series bkg2022a as defined above. The results of the radio source positions were submitted to IVS in IERS format. The TRF solution is made available in SINEX format version 2.1 and includes the 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**
  Calc/Solve allows the generation of so-called tropospheric path delay (TRP) files, which deliver the parameter estimates based on the Vienna Mapping Function (VMF1/VMF3) data. The TRP files contain the following information to describe the troposphere on a scan-by-scan basis: the a priori delay, dry and wet mapping functions, and the gradient mapping functions. The VMF3 data were downloaded daily from the server of the Vienna University of Technology [7]. The VLBI group of BKG continued the regular submissions of long time series of tropospheric parameters in the SINEX format as the tropospheric product to the IVS (wet and total zenith delays and horizontal gradients) for all VLBI sessions since 1984. In 2022, a new tropospheric parameter time series bkg2022a was created in addition to the bkg2020a series based on a global solution with a priori ITRF2020. The tropospheric parameters were extracted from the standard global solutions and transformed into tropospheric SINEX format for both IVS submissions: bkg2020a and bkg2022a.
- **Daily SINEX files**
  The VLBI group at BKG supports the regular submissions of daily SINEX files (bkg2020a) for all available 24-hour sessions to contribute to the IVS combined products and for the IVS time series of baseline lengths. The daily SINEX files include the session-wise 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. A second series of daily SINEX files (bkg2022a) was generated with a priori ITRF2020 with no further changes regarding the solution strategy.
- **SINEX files for *Intensive* sessions**
  The creation of SINEX files for all *Intensive* sessions (bkg2020a) continued. Also another set of SINEX files for *Intensive* sessions (bkg2022a) was generated based on a priori ITRF2020. The following estimated parameters are delivered in SINEX files: station coordinates, pole coordinates and their rates, and UT1-TAI and its rate. The normal equations stored in the SINEX files are feasible for further intra-technique combination or combination with other space geodetic techniques.
- **Contribution to ITRF2020**
  In 2021, the BKG Analysis Center submitted the remaining SINEX files for 24-hour sessions to support the IVS Combination Center to build the combined solution as the IVS contribution to ITRF2020. There is no difference in the parameterization with respect to our IVS product – daily SINEX files bkg2020a.
- **Contribution to EU-VGOS and PWLO projects**
  We are involved in the EU-VGOS collaboration [2], in which Anastasiia Walenta takes care of the organization of the analysis group activity, where the analysis results are presented and discussed.
  In the last year we have taken part in the PWLO project, where the SINEX files were prepared. The scope of the project was presented [3].

3 Developments

Currently we are also looking into VLBI data analysis using the *Bernese GNSS Software* [8]. This software package is used at BKG for GNSS and SLR data processing so far. We commissioned the Astronomical Institute of the University of Bern, Switzerland (AIUB), to enhance the *Bernese GNSS Software* in order to process VLBI data. This work is still under development. We expect a first basic version to be available for BKG within this year. It will allow us to process vgosDB data version 4 and will not only be used for VLBI data analysis and comparisons but also for the combination of the different space-geodetic techniques VLBI, SLR, and GNSS.

4 Personnel

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5 Future

We are interested to learn how to bridge data analysis and correlation. The availability of level 1 data facilitates the analysis group's learning of its capabilities in order to improve the obtained results and, thus, IVS products. Besides, we are going to consider the analysis optimization options in view of the growing amount of the coming VLBI observations.

References

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