Pulkovo Observatory (PUL) Analysis Center Report 2021–2022

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Abstract This report briefly presents activities of the IVS Analysis Center at the Pulkovo Observatory (PUL) during 2021–2022 and plans for the coming years. The main topics of the scientific investigations at the PUL AC in that period were ICRF-related studies and research in the field of Earth rotation and geodynamics. Regular activities include computation of CPO and FCN models (series), OCARS catalog support, and support of the PUL archives of data and products.

1 General Information

The PUL IVS Analysis Center was organized in September 2006. It is located at and sponsored by the Pulkovo Observatory of the Russian Academy of Sciences. It is a part of the Pulkovo EOP and Reference Systems Analysis Center (PERSAC) [1]. The main topics of our IVS-related activity in 2021–2022 were:

- Improvement of the International Celestial Reference Frame (ICRF).
- Analysis of Earth rotation parameters (EOP).
- Modeling of the celestial pole offset (CPO) and free core nutation (FCN).
- Computation and analysis of IVS observation statistics.

The PUL IVS AC webpage [2] is supported, which presents general information about the AC and obtained results.

Pulkovo Observatory

Pulkovo Analysis Center (PUL)

IVS 2021+2022 Biennial Report

2 Staff

The following persons contributed to the PUL activity in 2021–2022:

1. Zinovy Malkin (80%).

3 Activities and Results

3.1 General Activities

Team members participated in the activity of several International study groups such as IAU WG “Multi-waveband International Celestial Reference Frame (optical+VLBI)” in preparation of the next generation ICRF, IAG/IAU/IERS Joint WG “Consistent realization of TRF, CRF, and EOP” (CRTCE), IAG Sub-Commission 1.4 “Interaction of Celestial and Terrestrial Reference Frames”, and IAU/IAG Joint WG “Improving Theories and Models of the Earth’s Rotation” (ITMER).

3.2 ICRF-related Research

- Support of the OCARS catalog (Optical Characteristics of Astrometric Radio Sources) [3] continued. This compiled catalog provides VLBI and *Gaia* positions, source type, redshift info, photometric data in 13 visual bands (including three *Gaia* bands) and three NIR bands, and a cross-identification table with general radio, optical, NIR, Gamma-ray, X-ray, and UV catalogs for 13,690 radio sources (as of December 2022). The OCARS catalog is updated every several weeks and is available on the PUL webpage [4]. Starting in 2022, each OCARS release consists of six files:

`ocars.txt`	main catalog file
`ocars_p.txt`	VLBI position data
`ocars_g.txt`	Gaia astrometric data
`ocars_m.txt`	photometry data
`ocars_n.txt`	cross-identification table
`ocars.csv`	OCARS in CSV format

- Some new considerations for extending the ICRF source list were discussed in [5]. Statistical analysis of the ICRF catalog allows us to identify less populated sky regions where new ICRF sources or additional observations of the current ICRF sources are most desirable to improve both the uniformity of the source distribution and the uniformity of the distribution of the position errors. It is also desirable to include more sources with a high redshift in the ICRF list. These sources may be of interest for astrophysics. To select prospective new ICRF sources, the OCARS catalog is used. The number of sources in OCARS is about three times greater than in the ICRF3, which gives us an opportunity to select new ICRF sources that were already tested and detected in astrometric and geodetic VLBI experiments.
- To mitigate the impact of outliers on the results when comparing source position catalogs, a new method is proposed in [6], which is based on pixelization data over the equal-area cells, followed by median filtering of the data in each cell. After this, a new data set is formed, consisting of data points near-uniformly distributed over the sphere. The vector spherical harmonics (VSH) decomposition is then applied to this data to finally compute the orientation parameters between ICRF and *Gaia* frames. Several tests with the ICRF3, *Gaia* DR2, and OCARS catalogs showed that the proposed method is practically insensitive to outliers and thus provides robust results of catalogs comparison.
  Further investigation of two possible sources of random and systematic errors of this method was continued in [7]. Based on several computational tests, the dependence of the results of the determination of the orientation parameters between the ICRF and Gaia-CRF catalogs on the number of cells and on the displacement of the pixelization grid relative to the right ascension origin was estimated. It was found that the results of computations obtained in different test variants differ noticeably, but these differences are within the formal errors of the orientation parameters. Additional tests showed that the main source of these differences is an uneven distribution of the common sources in the compared catalogs over the celestial sphere.

3.3 Earth Rotation Research

- Team members contributed to the investigation of the interconnection between celestial pole motion (CPM) and geomagnetic field (GMF) [8]. The study was based on a joint analysis of the VLBI CPO series and GMF parameters. The results of this study reveal interesting common features in the CPM and GMF variations, which show the potential to improve the understanding of the GMF contribution to the Earth's rotation. Special attention was given to the investigation of the signal correlation between the FCN and GMF, and time lag between geomagnetic jerks and rotational variations.
- A new large jump in the FCN phase in 2022 was detected in [9]. This is only the second such large FCN phase jump in more than 30 years of FCN monitoring by means of VLBI technique. The new event was revealed and confirmed by analyzing two FCN models derived from a long-time series of VLBI observations. A connection of the new FCN phase jump with the recent geomagnetic jerk that started in 2020 is suggested.
- Team members contributed to an investigation of the combined effect of modeling Galactic aberration and ICRF evolution on the EOP derived from VLBI observations [10]. Moving from ICRF2 to ICRF3 leads to constant offsets of 3–15 microarcseconds in dX, dY, and UT1. The GA effect was found to be approximately 0.3 ± 0.3 μas/yr in dY only, which may impact on the results of precession modeling. The performed analysis showed that the VLBI network evolution is an additional factor influencing the GA effect. It decreases when using a set of more uniformly distributed sources or stations in most recent decades.

3.4 Other IVS-related Research

- A correction to paper [11] was published in [12] related to the history of the term "radio astrometry." In the introduction to the original paper, it was written:

  > "This can be considered the beginning of the radio astrometry era, although the term itself appeared apparently in the early 1970s (the earliest paper containing this term found by the author was dated 1973)."

  After publication of this paper, the author found the text of the lecture given by Thomas Clark at the Institute of Applied Astronomy in 2005 [13]. In this lecture, Clark quoted his note addressed to Robert Coates on February 27, 1969, where he had written:

  > "we hope to measure positions [of radio sources] to similar accuracies—seconds of arc. These measurements might best be called "Radio Astrometry."

  Thus, the term radio astrometry appeared as early as in 1969, several years earlier than it was assumed in [11].

3.5 Regular Activities

- Computation of two CPO and two FCN series. Some series also include prediction. All the computed series are based on the analysis of the IVS combined CPO solution. The resulting series are available on the PERSAC webpage [1].
- Archiving IVS data in the NGS cards format.
- Archiving IVS and IERS products.
- Development of algorithms and software for data processing and analysis continued.

4 Future Plans

Plans for the coming years include:

- Continuing ICRF-related studies.
- Continuing research on Earth rotation and geodynamics based on VLBI and other space geodesy observations.
- Continuing support of the OCARS catalog.

References

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