Pulkovo Observatory (PUL) Analysis Center Report

Zinovy Malkin

Abstract This report briefly presents activities of the IVS Analysis Center at the Pulkovo Observatory (PUL) during 2023–2024 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 2023–2024 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 web page [2], which presents general information about the AC and obtained results, is supported.

Pulkovo Observatory

Pulkovo Analysis Center (PUL)

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2 Staff

The following persons contributed to the PUL activity in 2023–2024:

1. Zinovy Malkin (80%).

3 Activities and Results

3.1 ICRF-related Research

- Support of the Optical Characteristics of Astrometric Radio Sources (OCARS) catalog [3] continued. This compiled catalog provides VLBI and *Gaia* positions, source types, redshift information, 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 2024). The OCARS catalog is updated every several weeks and is available on the PUL web page [4]. Starting in 2022, each OCARS release consisted 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

  In November 2024, support for the file `ocars_p.txt` was discontinued.
- In cooperation with OPA IVS AC (S. Lambert) several methods were compared for modeling large-scale systematic differences between cata-

logs of radio source positions with an emphasis on mitigating the impact of outliers [5]. VSH coefficients up to l=2 were solved using the least-squares method (L2-norm) and by L1-norm minimization with several methods of outlier detection. The methods were applied to both simulated and real catalogs. In simulations, the L1 minimization appears practically insensitive to outliers, and the L2-norm solution preceded by L1-norm-based outlier detection performed similarly. The results obtained with the cell median method are close to the modeled values within one microarcsecond. When applied to real catalogs, all methods provided close results within a few microarcseconds.

- The problem of accurate accounting for the Galactic aberration (GA) constant was addressed in [6]. There are several estimations of the GA constant (GA amplitude) derived from VLBI and *Gaia* data processing which differ significantly. Therefore, it is highly desirable to use an independent method to solve the problem of discrepancy between the GA values obtained with VLBI and *Gaia*. As such a method, the determination of the Galactic rotation parameters by stellar astronomy methods can be considered. The result obtained in this study showed that the GA constant estimate obtained from stellar astronomy is much closer to the GA constant estimate obtained from *Gaia*.
- A new analysis was performed to assess the long-term stability of radio (ICRF) and optical (*Gaia*-CRF) ICRS realizations [7]. Based on the 16-parameter vector spherical harmonics expansion of the differences between the three ICRF catalogs, it can be concluded that the mutual orientation between them is at a level of a few tens of microarcseconds, while the components of the glide vector and E2,0 term are several times greater. For the latest *Gaia*-CRF catalog, *Gaia*-CRF3, all rotational and deformation components are below 20 μas except for the E2,0 term, which is several times greater. For both ICRF and *Gaia*-CRF catalogs, the evolution of the errors in source position was also tracked. It was confirmed that the GA effect does not significantly impact the rotation vector, but accounting for the GA is crucial for the components of the glide vector. Other coefficients of the VSH expansion did not depend much on the GA, as expected.
- In many astronomical works, the structure of vector fields was analyzed, such as the differences in the celestial object coordinates in catalogs or the celestial object velocities, by decomposition into vector spherical harmonics (VSH). This method has shown high efficiency in many studies, but, at the same time, comparing the results obtained by different authors can cause difficulties associated with different approaches to building the VSH system and even with their different designations. To facilitate this task, a study was conducted to compare the three VSH systems most often used in works on astrometry and stellar astronomy [8].

3.2 Earth Rotation Research

- Recently, it has been suggested by Agnew (Agnew, 2024, Nature, 628, 333) that UT1-UTC could reach a large positive value in the coming years. This would make it necessary to introduce a negative leap second into UTC for the first time in history, which in turn will cause serious problems in time keeping and synchronization systems around the world. Based on the latest IERS data and its prediction, it was shown that the acceleration trend observed over the past four years is likely to return to slowing down soon [9]. Therefore, concerns about the possible need to introduce a negative leap second in UTC in the next few years appear to be unfounded in light of recent observational data.

3.3 Regular Activities

- Participation in the activity of several international study groups of the IAU and IAG
- Computation of CPO and FCN series, with some series also including prediction. All the computed series are based on the analysis of the IVS combined CPO solution. The resulting series are available on the PERSAC web page [1].
- Archiving IVS data in the NGS cards format
- Archiving IVS and IERS products
- Continuation of the development of algorithms and software for data processing and analysis.

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 observations
- Continuing support of the OCARS catalog.

References

1. http://www.gaoran.ru/english/as/persac/
2. http://www.gaoran.ru/english/as/ac_vlbi/
3. Malkin Z. A new version of the OCARS catalog of optical characteristics of astrometric radio sources. Astrophys. J. Suppl., 2018, V. 239(2), id. 20. DOI: 10.3847/1538-4365/aae777
4. http://www.gaoran.ru/english/as/ac_vlbi/#OCARS
5. Lambert S., Malkin Z. Estimation of large-scale deformations in VLBI radio source catalogs with mitigation of impact of outliers: A comparison between different L1- and L2-norm-based methods. Astron. Astrophys., 2023, Vol. 669, id. A138 (7 pp.). DOI: 10.1051/0004-6361/202244837
6. Malkin Z. On the Most Reliable Value of the Galactic Aberration Constant. Res. Notes AAS, 2023, Vol. 7(6), id. 133. DOI: 10.3847/2515-5172/ace050
7. Malkin Z. How Well is the International Celestial Reference System Maintained in Official IAU Implementations? Astron. J., 2024, Vol. 167, No. 5, id. 229. DOI: 10.3847/1538-3881/ad35bf
8. Malkin Z. M. On the Use of Vector Spherical Harmonics. https://arxiv.org/abs/2410.06075
9. Malkin Z. M. Should We Expect Further Acceleration of the Earth's Rotation in the Coming Years? Astron. Rep., 2024, Vol. 68, No. 10, 1022–1028. DOI: 10.1134/S1063772924700884