

# Pulkovo IVS Analysis Center (PUL) 2012 Annual Report

Zinovy Malkin, Julia Sokolova

## Abstract

This report briefly presents the PUL IVS Analysis Center activities during 2012 and plans for the coming year. The main topics of the investigations of PUL staff in that period were ICRF related studies, computation and analysis of EOP series, celestial pole offset (CPO) modeling, and VLBI2010 related issues.

## 1. General Information

The PUL IVS Analysis Center (AC) was organized in September 2006 and 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 are:

- Improvement of the International Celestial Reference Frame (ICRF).
- Computation and analysis of the Earth orientation parameters (EOP) from Intensives and 24-hour IVS sessions.
- Modeling of the celestial pole offset (CPO) and free core nutation (FCN).
- Comparison of VLBI products, primarily as Earth orientation parameters (EOP), with results of other space geodesy techniques.
- Computation and analysis of observation statistics.

The PUL AC's Web page [2] is supported. It contains the following sections:

- *General Information on the PUL AC.* Includes brief history, activity overview, and a scientific staff list.
- *VLBI data analysis.* Includes results of VLBI data analysis, such as UT1 Intensive series, CPO/FCN series, and mean Pole coordinates. These data are updated daily.
- *OCARS catalog.* Includes the latest version of the catalog of optical characteristics of astrometric radio sources (OCARS) [3]. The catalog is continually updated as new information becomes available.
- *Approaches and occultations.* Includes tables for forthcoming mutual events of planets and astrometric radio sources, such as close angular approaches and occultations for the period until 2050 [4].
- *PUL members' publications and presentations.*
- *VLBI technology overview.*
- *Links to the VLBI World.* Includes links to (primarily geodetic and astrometric) VLBI coordinating bodies, stations, analysis centers, software, etc.
- *Contact information.*

## 2. Scientific Staff

In 2012 the following persons contributed to the PUL activity:

1. Zinovy Malkin (70%) — PUL coordinator, EOP and CRF analysis;
2. Natalia Miller (5%) — EOP analysis;
3. Julia Sokolova (100%, since August 2012) — CRF analysis.

## 3. Activities and Results

The main activities and results of the PUL IVS Analysis Center during 2012 included:

- Operational processing of the IVS Intensive sessions in automated mode and submission of results to IVS was continued.
- ICRF related research was continued. The main directions of this activity were comparison and combination of radio source catalogs and investigation of their stochastic and systematic errors. In 2012, the following results were obtained.
  - A new Pulkovo combined catalog was computed [5]. Using CRF realizations from seven IVS ACs (bkg, cgs, gsf, igg, opa, sha, and usn) we computed two combined catalogs PUL(2012)C01 and PUL(2012)C02. Besides using more data, several developments were realized as compared with the previous version of Pulkovo combined catalog of 2007 [6]. The PUL(2012)C01 catalog is constructed in the ICRF2 system and is aimed at improvement of the ICRF2 random errors, and the PUL(2012)C02 catalog is constructed in an independent system and thus provides both stochastic and systematic improvement of the ICRF2.
  - Several related studies were conducted [7, 8].
- CPO and FCN related researches. The main activities and results in 2012 were the following.
  - Two CPO and two FCN series were updated daily and made available at the PERSAC Web site. One CPO and one FCN series were started at the end of 2012.
  - Comparison of several CPO series were made from the eight individual ones computed at IVS ACs (aus, bkg, cgs, gsf, iaa, opa, sopu, and usn) and combined solutions of IVS and IERS (C04 and NEOS) [9]. It has been shown that significant random and systematic errors between these series do exist and in turn lead to differences and inconsistencies between results of users' applications. This situation requires clear IVS and IERS recommendations on using different CPO series.
  - Joint analysis of the Polar Motion and CPO time series was made along with time series of two geomagnetic indices, Kp and Dst [10]. Two groups of common principal components (PCs) were found: trends, and quasi-harmonic terms with near-Chandlerian frequencies for PM, Kp, and Dst series, and near-FCN frequency for CPO series (both periods are near 430 days). Comparison of the spectra of the investigated series and their amplitude and phase variations showed some interesting common features. However, the obtained results are still not sufficient to quantify the effects of interconnections of the Chandler Wobble (CW), FCN, and the geomagnetic field.

- Investigations of the impact of the Galactic aberration on the ICRS realization and EOP were continued in cooperation with Paris Observatory and Nanjing University [11, 12]. It was shown that the effect of the Galactic aberration strongly depends on the distribution of the sources that are used to realize the ICRS. According to different distributions of sources the amplitude of the apparent rotation of the ICRS is between about 0.2 and 1  $\mu\text{as}/\text{yr}$ . This rotation has no component around the axis pointing to the Galactic center and has zero amplitude in the case of uniform distribution of sources. The effect on the coordinates of the Celestial intermediate pole (CIP) is between about 1 to 100  $\mu\text{as}/\text{cy}$ , and the effects on the Earth rotation angle (ERA) are from four to several tens of  $\mu\text{as}/\text{cy}$ .
- Studies have been conducted in the framework of the IAG SC 1.4 activity on investigation of the mutual impact of celestial and terrestrial reference frame and related issues such as systematic errors of the ICRF, impact of astronomical and geophysical modeling on the CRF and TRF results, and future prospects of improvement of the ICRF systematic accuracy [13, 14, 15].
- The work on the OCARS catalog [3] was continued. The current basic statistics of the catalog are the following.

	OCARS	ICRF2	ICRF2 def.
Sources	7174	3414	295
Sources with known redshift	3927 (54.7%)	2199 (64.4%)	257 (87.1%)
Sources with known magnitude	4861 (67.8%)	2589 (75.8%)	284 (96.3%)

- A catalog of approaches of planets to radio sources and occultations of astrometric radio sources by planets through the year 2050 was updated [4].
- The PUL archive of VLBI data and products is supported. At present, all available databases and corresponding NGS cards for 1979-2012 have been stored (about 9.4 million observations) along with the main IVS and IERS products. These archives are continually updated as new databases becomes available.
- Development of algorithms and software for data processing and analysis continued.
- PUL staff members participated in activities of several IERS, IAG, and IVS projects, committees, and working groups.

#### 4. Outlook

Plans for the coming year include:

- Continue VLBI related studies.
- Continue UT1 Intensive processing.
- Continue OCARS catalog support.
- Continue development of algorithms and software for data processing.
- Continue support of the PUL archives of data and products.

## References

- [1] <http://www.gao.spb.ru/english/as/persac/index.htm>
- [2] [http://www.gao.spb.ru/english/as/ac\\_vlbi/](http://www.gao.spb.ru/english/as/ac_vlbi/)
- [3] [http://www.gao.spb.ru/english/as/ac\\_vlbi/ocars.txt](http://www.gao.spb.ru/english/as/ac_vlbi/ocars.txt)
- [4] [http://www.gao.spb.ru/english/as/ac\\_vlbi/occultations\\_approaches.pdf](http://www.gao.spb.ru/english/as/ac_vlbi/occultations_approaches.pdf)
- [5] Sokolova Ju., Malkin Z. New Pulkovo combined catalogs of the radio source positions. Presented at the IAU XXVIII General Assembly, Beijing, China, August 2012.
- [6] Sokolova Ju., Malkin Z. On comparison and combination of catalogs of radio source positions. *Astron. Astrophys.*, 2007, 474, 665–670.
- [7] Sokolova Ju., Malkin Z. Impact of covariance information on the orientation parameters between radio source position catalogs. In: *IVS 2012 General Meeting Proceedings*, ed. D. Behrend, K.D. Baver, NASA/CP-2012-217504, 2012, 339-341.
- [8] Malkin Z. On assessment of stochastic errors of radio source position catalogs. Presented at the IAU XXVIII General Assembly, Beijing, China, August 2012.
- [9] Malkin Z. Celestial pole offsets: from initial analysis to end user. *IVS 2012 General Meeting Proceedings*, ed. D. Behrend, K.D. Baver, NASA/CP-2012-217504, 2012, 375-379.
- [10] Miller N., Malkin Z. Joint analysis of the Polar Motion and Celestial Pole Offset time series. In: *IVS 2012 General Meeting Proceedings*, ed. D. Behrend, K.D. Baver, NASA/CP-2012-217504, 2012, 385-389.
- [11] Malkin Z. On the impact of the Galactic aberration on VLBI-derived precession model. In: Schuh H., Boehm S., Nilsson T., Capitaine N. (Eds.) *Proc. Journées 2011: Earth rotation, reference systems and celestial mechanics: Synergies of geodesy and astronomy*, Vienna, Austria, September 19-21, Vienna: Vienna University of Technology, 2012, 168–169.
- [12] Liu J.-C., N. Capitaine, S.B. Lambert, Z. Malkin, Z. Zhu. Systematic effect of the Galactic aberration on the ICRS realization and the Earth orientation parameters. *Astron. Astrophys.*, 2012, v. 548, A50.
- [13] Malkin Z., Schuh H., Ma C., Lambert S. Interaction between celestial and terrestrial reference frames and some considerations for the next VLBI-based ICRF. In: Schuh H., Boehm S., Nilsson T., Capitaine N. (Eds.) *Proc. Journées 2011: Earth rotation, reference systems and celestial mechanics: Synergies of geodesy and astronomy*, Vienna, Austria, September 19-21, Vienna: Vienna University of Technology, 2012, 66–69.
- [14] Boehm J., Malkin Z., Lambert S., Ma C. Challenges and Perspectives for TRF and CRF Determination. In: *IVS 2012 General Meeting Proceedings*, ed. D. Behrend, K.D. Baver, NASA/CP-2012-217504, 2012, 309-313.
- [15] Malkin Z. Connecting terrestrial to celestial reference frames. Presented at the IAU XXVIII General Assembly, Beijing, China, August 2012.