

Pulkovo IVS Analysis Center (PUL) 2013 Annual Report

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Abstract This report briefly presents the PUL IVS Analysis Center activities during 2013 and plans for the coming year. The main topics of the investigations of the PUL staff in that period were ICRF related studies, computation and analysis of EOP series, celestial pole offset (CPO) and free core nutation (FCN) modeling, and VLBI2010 related issues.

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 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.
- Analysis of EOP and position time series.
- Modeling of the celestial pole offset (CPO) and free core nutation (FCN).
- Comparison of VLBI products, primarily EOP, with results of other space geodesy techniques.
- Computation and analysis of observation statistics.

The PUL Analysis Center Web page [2] is supported. It contains the following sections:

Pulkovo Observatory

Pulkovo Analysis Center (PUL)

IVS 2013 Annual Report

- *General Information on the PUL Analysis Center.* 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 Staff

In 2013 the following persons contributed to the PUL activity:

1. Zinovy Malkin (70%) — team coordinator, EOP and CRF analyst;
2. Natalia Miller (5%) — EOP analyst; and
3. Yulia Sokolova (100%) — CRF analyst.

3 Activities and Results

The main activities and results of the PUL IVS Analysis Center during 2013 included:

- *ICRF related research.* The main directions of this activity were comparison and combination of radio source catalogs and investigation of their stochastic and systematic errors. In 2013, the following results were obtained:
 - A new Pulkovo combined catalog was computed [5]. Using CRF realizations from eight IVS Analysis Centers (aus, bkg, cgs, gsf, igg, opa, sha, and usn), we computed two combined catalogs: PUL (2013) C01 and PUL (2013) C02. The method used generally follows our previous work [6]. Besides using more data, several developments were realized as compared with the previous version of the Pulkovo combined catalog of 2007 [6]. The PUL (2013) C01 catalog is constructed in the ICRF2 [7] system and is aimed at improving ICRF2 random errors, while the final, PUL (2013) C02 catalog is constructed in an independent system and thus provides both stochastic and systematic improvement of the ICRF2. Comparison of the Pulkovo combined catalog with ICRF2 gives evidence of ICRF2 systematic errors at a level of 15–20 μ as.
 - Impact of the correlation information on the results of determination of the angles of mutual orientation between catalogs was investigated [8]. This work continues the work of Jacobs et al. [9]. Test computations were performed with nine catalogs computed in eight centers of analysis of the VLBI observations. The mutual orientation between these CRF realizations was computed with three methods of accounting for the correlation information: using the position errors only, using only the RA/DE correlations reported in radio source position catalogs in the IERS format, and using the full correlation matrix. Only two of these catalogs, igg and gsf, were provided together with full covariance matrices (thanks to the authors of these catalogs who made them available for our work); seven other catalogs were published with RA/DE correlations only. Our analysis has shown that using the RA/DE correlations only slightly influences the computed rotational angles, whereas using the full correlation matrices leads to substantial change in the orientation parameters between the compared catalogs.
 - A new approach to estimation of the stochastic errors of radio source position catalogs was proposed [10]. It is based on the three-cornered-hat technique, extended to the N-cornered-hat technique. A key point of the method is a new approach to computation of the correlations between the compared catalogs. As an additional refinement, the concept of weighted correlation coefficient was introduced. This technique was applied to nine recently published radio source position catalogs. We also found large systematic differences between catalogs that significantly impact determination of their stochastic errors.
 - A study was performed aimed at a search for an optimal strategy for using limited observational resources in the southern hemisphere to improve ICRF in the band $\delta < -40^\circ$ [11]. We investigated the possibility of increasing the number of observations of existing and prospective southern ICRF radio sources by inclusion of more such sources in the regular IVS sessions like R1 and R4. With Monte Carlo simulations, we tested the influence of adding supplementary southern sources to the IVS R1541 (12JUL09XA) session on EOP and baseline length repeatability. We found that adding more observations of southern sources to the standard schedule causes a slight degradation of some geodetic products and a slight improvement of others, depending on the number of added southern sources. Similar results were obtained for the IVS R1591 (13JUN24XA) session. Generally, it was shown that it is possible to increase the number of observations of southern sources without loss of the overall accuracy of geodetic products.
 - The OCARS catalog [3] has been supported since 2008. The catalog provides redshift information, as well as visual and NIR magnitudes. The improvements made in 2013 include addition of new sources and new measurements of redshift and magnitude. The current basic statistics of the catalog are given in Table 1.

Table 1 Current basic statistics of the OCARS catalog.

	All sources	ICRF2 sources	ICRF2 defining
Sources	8246	3414	295
Sources with known redshift	4353 (52.8%)	2249 (65.9%)	261 (88.5%)
Sources with known magnitude	5395 (65.4%)	2618 (76.7%)	285 (96.6%)

- *CPO and FCN related research.* The main activities and results in 2013 were the following:
 - Two CPO and two FCN series were updated daily and are available at the PERSAC Web page [1].
 - FCN amplitude and phase variations derived from VLBI observations were investigated. Comparison of the epochs of the changes in the FCN amplitude and phase with the epochs of the geomagnetic jerks (GMJs) indicated that the observed extremes in the FCN amplitude and phase variations were closely related to the GMJ epochs. In particular, the FCN amplitude begins to grow one to three years after the GMJs. Thus, processes that cause GMJs are assumed to be sources of FCN excitation [13].
 - Several VLBI-derived CPO time series were analyzed with the goal of detecting the Free Inner Core Nutation (FICN) [14]. The series were investigated by means of spectral and wavelet analysis. It was shown that there are several periodic signals with close amplitude around the expected FICN period without a prevailing one, which can be associated with the FICN. So, it seems to be necessary to improve the theoretical estimates of the FICN period to make searching for it in the observational series more promising.
 - A study was made to investigate optimal CPO modelling for operational determination of UT1 from hourly sessions with the Quasar VLBI network (Institute of Applied Astronomy). It was found that the systematic differences between the UT1 estimates computed with different models (trend and seasonal terms) are at a level of 1-3 μ s. On the other hand, the formal error of the UT1 estimates practically does not depend on the CPO model used [12].
- *Studies in the framework of the IAG SC 1.4 activity* on investigation of the mutual impact of celestial and terrestrial reference frames and impact of astronomical and geophysical modelling on ICRF.

A study was performed to investigate the impact of seasonal station movement on the UT1 Intensive results [15]. It was found that a significant annual term is present in the time series for most stations, and its amplitude can reach 8 mm in the height component and 2 mm in the horizontal components. However, the annual signals found in the displacements of the co-located VLBI and GPS stations at some sites differ substantially in amplitude and phase. The semiannual harmonics are relatively small and unstable, and for most stations no prevailing signal was found in the corresponding frequency band. Then two UT1 Intensive series were computed with and without including the seasonal term found in the previous step in the station movement model. Comparison of these series has shown that neglecting the seasonal station position variations can cause a systematic error in UT1 estimates, which can exceed 1 μ s, depending on the observing program.

- Operational data processing of IVS Intensive sessions in automated mode and submission of results to IVS was continued. The UT1 time series is available at IVS Data Centers and at the PERSAC Web page [1].
- The PUL archive of VLBI data and products obtained in the framework of IVS activity is supported. At present, all available databases and corresponding NGS cards for 1979-2013 are stored (about 9.4 million observations) along with the main IVS and IERS products. These archives are continually updated as new databases become available.
- Development of algorithms and software for data processing and analysis continued. The results of two studies were published in 2013. The first paper deals with improvement of the application of the Allan variance technique to astronomical and geodetic time series with unevenly weighted measurements [16]. Modifications of the standard AVAR definition for unevenly spaced and multi-dimensional series were proven to be an effective

tool for data processing. In the second study, the problem of computation of the uncertainty of a weighted mean of several measurements was considered [17]. It was found that two classical approaches have serious shortcomings when applied to real data. Therefore, a combined estimate for the uncertainty of the weighted mean was proposed and successfully tested.

- PUL staff members participated in activities of several IERS, IAG, and IVS projects, committees, and working groups.

4 Future Plans

Plans for the coming year include:

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

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