Pulkovo IVS Analysis Center (PUL) 2014 Annual Report

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Abstract This report briefly presents the PUL IVS Analysis Center activities during 2014 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 source 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:

- *General information about 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 OCARS (Optical Characteristics of Astrometric Radio Sources) [3]. The catalog is regularly 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 2014 the following persons contributed to the PUL activity:

1. Zinovy Malkin (70%) — team coordinator, EOP and CRF analyst;
2. Yulia Lopez (née Sokolova) (100%) — CRF analyst.

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3 Activities and Results

The main activities and results of the PUL IVS Analysis Center during 2014 included:

- *ICRF-related research.* The main directions of this activity were comparison and combination of radio source position catalogs and investigation of their stochastic and systematic errors. In 2014, the following results were obtained:
  - A new method of investigation of the stochastic errors of external radio source position catalogs (RSPCs) has been tested [5]. Using this method the stochastic errors of nine recently published RSPCs were evaluated. It has been shown that the result can be affected by the systematic differences between catalogs if the latter are not accounted for. It was also found that the formal uncertainties of the source positions in the RSPCs correlate with the external errors. We also investigated several topics related to the formal uncertainties and systematic errors of RSPCs.
  - We continued investigations of the impact of the correlation information on the orientation parameters between celestial reference frames [6]. We compared results of determination of the orientation angles between celestial reference frames realized by radio source position catalogs using three methods of accounting for correlation information: using the position errors only, using additionally the correlations between the right ascension and declination (RA/DE correlations) reported in radio source position catalogs published in the IERS format, and using the full covariance matrix. The computations were performed with nine catalogs computed at eight analysis centers. 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.
  - *Studies related to modeling the Galactic aberration in source proper motions.*
    1. We analyzed all available determinations of the Galactic rotation parameters R_0 and Ω_0 made during the last ten years to derive the most probable value of the Galactic aberration constant $A = R_0\Omega_0^2/c$ [7]. We used several statistical methods to obtain reliable estimates of R_0 and Ω_0 and their realistic errors. As a result, we obtained the value of $A = 5.0 \pm 0.3$ μas/yr as the current best estimate of the GA constant. We suggest that the proposed value of the GA constant can be safely used in practice during coming years.
    2. During recent years, much attention has been paid to the astrometric implications of the galactic aberration in proper motions (GA). This effect causes systematic errors in astrometric measurements at the μas level. Some authors consider it so serious that it requires redefinition of the celestial reference frame (CRF). We argue that such attention to the GA is too much exaggerated. It is just a small astrometric correction that must be taken into account during highly accurate astrometric and geodetic data processing. The accuracy of this correction depends on the accuracy of the Galactic rotation parameters and, for most applications, on the accuracy of the rotation matrix between Galactic and equatorial systems. Our analysis has shown that our knowledge today of these two factors is sufficient to compute the GA correction with accuracy of better than 10%. The remaining effect at a level of few tenths μas/yr is negligible nowadays. Another consequence of introducing the GA correction is the necessity to return to classical astrometric modeling of the VLBI-derived extragalactic radio source positions by the linear trend model. Changing the current paradigm of VLBI-derived CRF based on the assumption of zero motion of radio sources to the classical one leads to bias in the radio source positions up to several tens of μas for catalogs at epoch J2000.0 [8].
  - 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 2014 include addition of new sources and new measurements of redshift and magnitude. A new file with detailed

photometric data, `ocars_m.txt`, is now supported in addition to the main OCARS catalog file, `ocars.txt`. The current basic statistics of the OCARS catalog are given in Table 1.

- *CPO and FCN related research.* The main activities and results in 2014 were the following:
  - Two CPO and two FCN series were updated daily and are available at the PERSAC Web page [1].
  - Several VLBI-derived CPO time series were analyzed with the goal of detecting the Free Inner Core Nutation (FICN) [9]. 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.
  - Corrections to the IAU 2000/2006 parameters of the theory of precession and nutation were calculated using five different series: two individual series and three combined series that have been used in the literature for this purpose. A comparison of the sets of corrections obtained using the different series indicates significant systematic differences between them, which often substantially exceed the corresponding random errors. At the same time, existing studies have usually used data obtained from one or two series chosen by the authors without special justification. When refining the theory of precession and nutation, it is necessary to consider and compare various available series of VLBI data if one wishes to reduce the systematic errors in an improved model [10].
- *Studies on investigation of the mutual impact of celestial and terrestrial reference frames, and impact of astronomical and geophysical modeling on ICRF.* Analysis of measurements of the space geodetic techniques requires the use of the best available models describing the deformation of the Earth's surface. The goal is to have a set of models which realistically describe changes in the station positions on the Earth's surface during the time when the observations are carried out. We take advantage of a long time span of measurements (more than 29 years) gathered by the Very Long Baseline Interferometry (VLBI) technique, and we focus on the propagation of these unmodeled effects in all three station coordinates to the radio source positions building the celestial reference frame (CRF). Two treatment approaches of the unmodeled seasonal station displacement are introduced. As the first, we model the surface deformation as a periodic movement with annual and semi-annual periods, and in the second approach we create an average annual model [11].
- 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—2014 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.
- 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 ICRF-related studies.
- Continuing CPO/FCN-related studies.
- Continuing UT1 Intensive data processing.
- Continuing OCARS catalog support.
- Continuing development of algorithms and software for data processing.
- Continuing support of the PUL archives of data and products.

Table 1 Current basic statistics of the OCARS catalog.

	All sources	ICRF2 sources	ICRF2 defining
Sources	9,049	3,414	295
Sources with redshift information	4,901 (54.2%)	2,332 (68.3%)	262 (88.8%)
Sources with photometric data	5,973 (66.0%)	2,643 (77.4%)	286 (96.9%)

References

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