OPERATIVE EOP ACTIVITIES AT VNIIFTRI

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ABSTRACT. VNIIFTRI as the Russian Main Metrological Center of Time, Frequencies and Earth Rotation Service has carried out rapid EOP processing based on GNSS, VLBI and SLR observations for many years. VNIIFTRI also participates in GNSS and SLR observations of IGS and ILRS respectively.
The EOP activities at VNIIFTRI can be grouped in five basic topics:
1) Processing of VLBI, GNSS, SLR and LLR observation data for EOP evaluation;
2) Evaluation of combined EOP values based on EOP series and SINEX combination;
3) Evaluation and combination of GLONASS satellites orbit/clock;
4) Satellite altimetry data processing;
5) Providing GNSS and SLR observations at five metrological sites acting under the auspices of VNIIFTRI.
These fields of activity are considered shortly.

1.INTRODUCTION

VNIIFTRI tparticipates in Earth's orientation parameters (EOP) activity as:

1) Russian Main Metrological Center of State Service for Time, Frequencies and Earth orientation parameters evaluation (MMC SSTF);

2) Analysis Center (AC) and regional Data Center for five measurement sites of metrological control of ROSSTANDART.

2. SITES OF METROLOGICAL CONTROL

2.1 Metrological control sites

GNSS observations on the five metrological control sites of Rosstandard (Mendeleevo (MDVJ), Novosibirsk(NOVM), Irkutsk (IRKJ), Khabarovsk and Petropavlovsk-Kamchatsky) are carried out permanently and hourly files are formed. SLR observations are carried out at Mendeleevo and Irkutsk using satellite laser range finders "Sazen-TM". So, Mendeleevo and Irkutsk are sites with colocation of GNSS and SLR (Ignatenko et al, 2016). MDVJ, NOVM, IRKJ are sites of the International GNSS Service (GNSS). MDVL and IRKL are sites of the International Laser Ranging Service (ILRS). MDVJ is included in EUREF GNSS Permanent Network (EPN). The results of GNSS observations are accumulated at VNIIFTRI in hourly mode and, as well as SLR data, they are used for rapid EOP evaluation. The direct results of SLR observations are transferred to the Information and Analysis Center (IAC) monitoring GLONASS observations and to ILRS.

2.2 Moving to sites of new generation

The two new laser range finders "Tochka" which meet the requirements SLR2000 were built in Mendeleevo (VNIIVTRI) and Irkutsk (North-Eastern branch of VNIIFTRI). These laser range finders have instrumental errors not exceeding a few millimeters for a single measurement and their

declared characteristics were confirmed through preliminary tests (Baryshnikov et al, 2019).

3. GNSS ORBITS AND CLOCK DETERMINATION

By now, GPS and GLONASS satellites orbits and clock corrections are determined at VNIIFTRI. Data processing is performed in three regimes:

1) Final: orbits and clock combination obtained by several Russian and IGS AC (Bezmenov and Pasynok, 2015);
2) Rapid: data processing of about 500 IGS and Russian sites for determination of own MMC SSTF orbits and clock corrections (Bezmenov and Pasynok, 2017);
3) Ultra rapid: processing hourly RINEX d/n/g data received from about 500 IGS and Russian sites and determination of own MMC SSTF orbits and clock corrections (Bezmenov, 2018);

Software for orbit /clock calculation in the first regime was entirely developed at VNIIFTRI. It is based on a well-known algorithm (Beutler et al,1996).

The softwares for orbit/clock calculation in the other regimes are based on BERNESE GNSS Software 5.2 developed at Astronomical Institute of the University of Bern (AIUB, Switzerland). Additional program modules were developed at MMC SSTF. The BERNESE GNSS Software 5.2 shell is used to input parameters for all programs. Some additional program units and associated panels were created. Test results obtained at VNIIFTRI for GLONASS satellites clock corrections (ultra-rapid mode) in comparison with other AC are shown in Figure **??**.

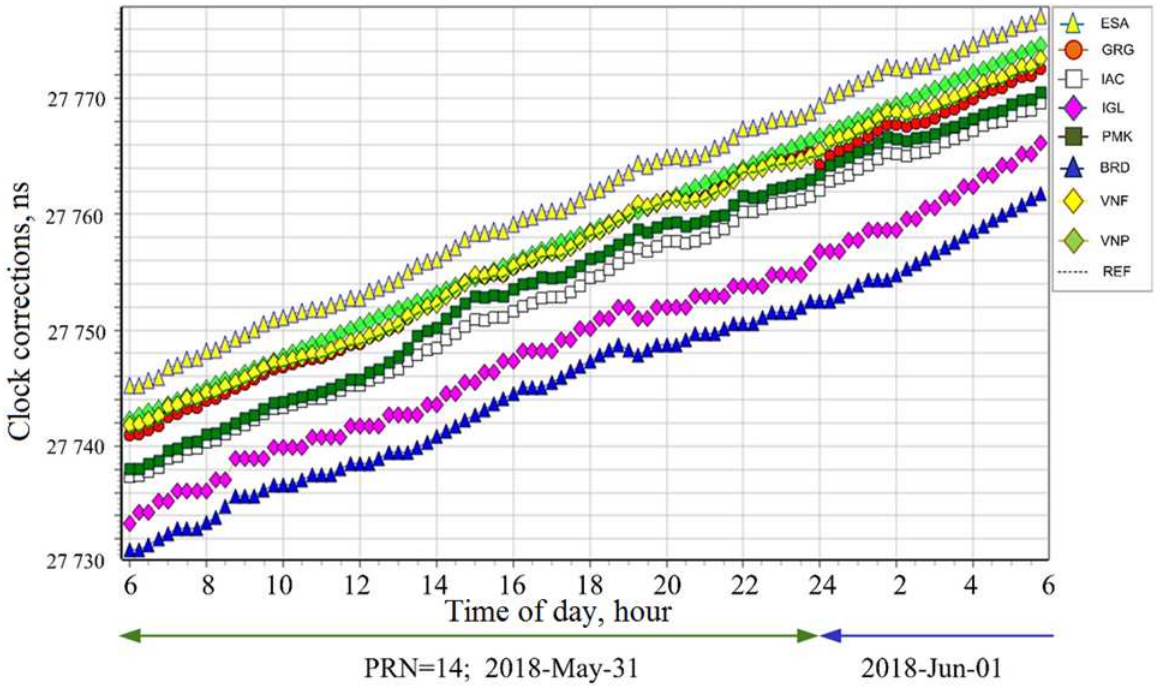

Figure 1: GLONASS Satellite clock corrections (PRN=R03) estimated at MMC SSTF in ultra rapid mode: VNF estimated part, VNP prediction part derived from the previous day. Comparison of estimated values of clock corrections with similar aposteriori values of other ACs and reference values (REF). The reference values were formed as weighted average data of other ACs. The inter daily jumps in ESA data were removed.

4. SATILLITE ALTIMETRY PROCESSING

The software for determination deflection of vertical (DOV), geoid heights (GH) and gravity anomalies (GA) has been also developed at VNIIFTRI. More informations can be found in (Tcyba, 2019).

5. EARTH ORIENTATION PARAMETERS EVALUATION

5.1 SLR and LLR processing for Earth orientation parameters evaluation

The daily processing of SLR Lageos-1 and Lageos 2 observations has been undertaken at MMC SSTF. The results can be seen in Figure **??**. The STD of pole coordinates x_p and y_p evaluation with respect oto EOP C04 values are 0.08 and 0.1 mas respectively.

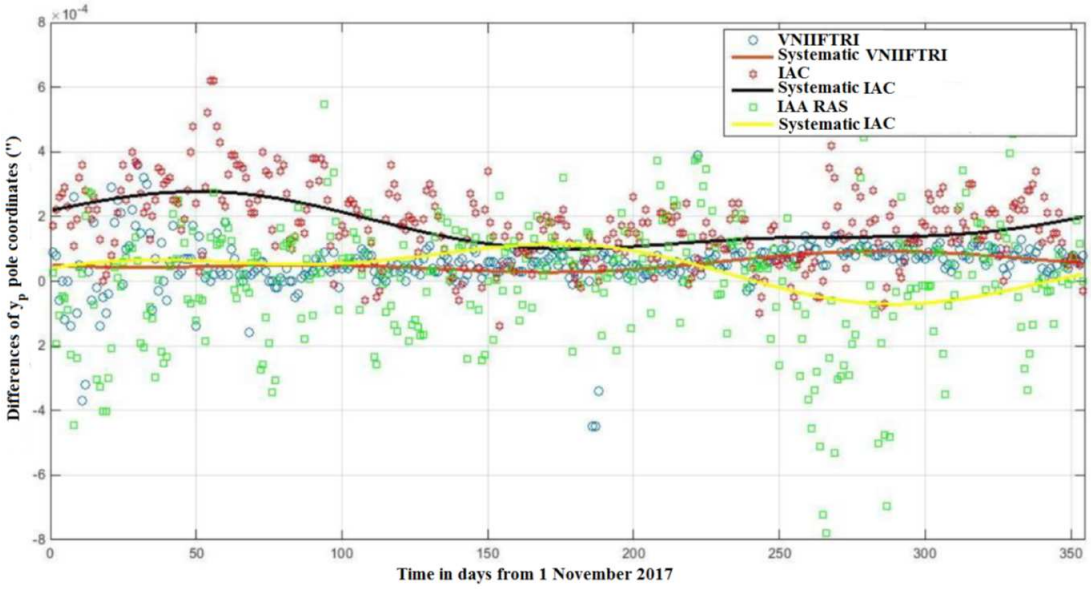

Figure 2: Comparison of SLR pole coordinates with EOPC04 values.

The modern program of UT1 evaluation based on Lunar Laser Ranging measurements was created in the MATLAB environment (Tcyba and Volkova, 2019).

Whereas only ILRS LLR data are processed, program for processing the Altay LLR station measurements has been set up. The main window interface of this software is shown in Figure **??**.

5.2 VLBI processing for Earth orientation parameters evaluation

For VLBI data analysis VNIIFTRI uses the ARIADNA software package developed by V. Zharov (2011). The version 4.11 of this software was finished and tested at the end of 2018 in the framework of the VLBI AC operating both at SAI (Sternberg Astronomical Institute of the Moscow State University) and VNIIFTRI. This version allows to read observation data in vgosDB format and to create SINEX files for hourly sessions. The daily processing IVS VLBI data for EOP evaluation are performed at VNIIFTRI now.

The comparison with other AC is showed in Figure **??**.

5.3 GNSS processing for Earth's orientation parameters evaluation

The GNSS processing of measurements and EOP evaluations are carried out using the BERNESE GNSS software developed in Astronomical Institute of the University of Bern (AIUB, Switzerland).

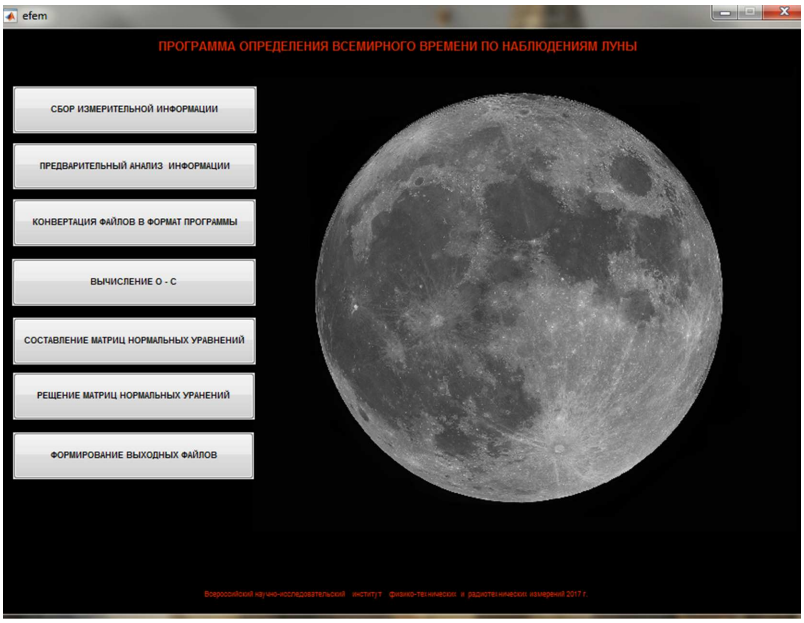

Figure 3: Main window of LLR UT1 software.

The actual algorithm was set up in 2006 with some changes (Kaufman, M., Pasynok S., 2010). It is based on the so-called method of Precise Point Positioning (PPP) using phase measurements with a-priori knowledge of precise satellites coordinates and onboard clocks biases for navigation tasks. Then the values of UT1 and pole coordinates are calculated using the calculated instantaneous coordinates of stations and their catalogue values. Processing is carried out separately for each daily session of measurements.

6. EARTH ORIENTATION PARAMETERS COMBINATION

Combination for operative EOP evaluation has been done at VNIIFTRI since 1955. Now two types of EOP combination are maintained: combination at time raw level and combination at normal equation level (see Figure **??**).

6.1 Combination on EOP time raws level

Combination EOP at time raw level are calculated at VNIIFTRI by combining nine independent individual EOP series provided by the following Russian analysis centers: VNF (VNIIFTRI), IAA (Institute of Applied Astronomy), IAC (Information-Analytical Center of Russian Space Agency) and SVOEVP (Russian Space Agency).

6.2 Combination on normal equation level

Combination EOP at normal equation level are calculated at VNIIFTRI by combining the SINEX files, mostly provided by international services.
The core of SINEX combination program - SINCom software package - has been developed at Institute of Applied Astronomy. The Perl scripts for automatisation of data preparation, realisation of calculation strategy, prediction and forming results were developed at VNIIFTRI.

7. CONCLUSION

We have presented an overview of EOP production and its main developments at VNIIFTRI in the frame of the Russian Main Metrological Center of Time, Frequencies and Earth Rotation

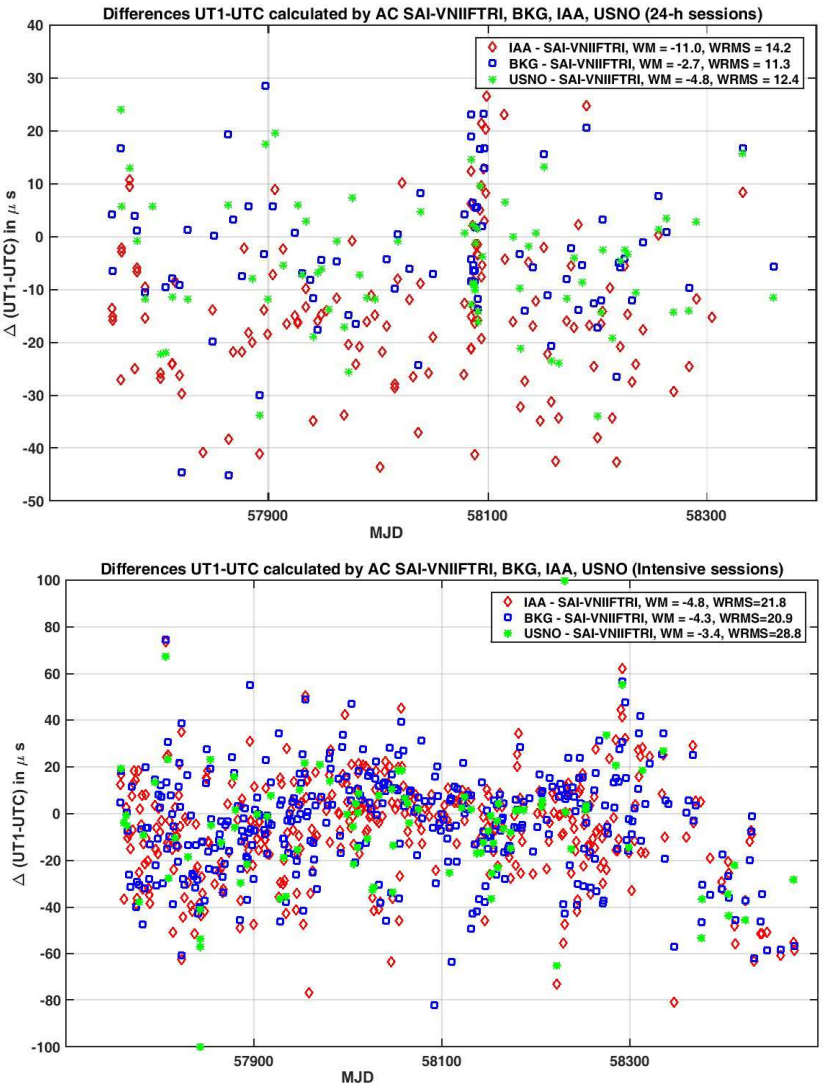

Figure 4: AC BKG, IAA, USNO - AC SAI-VNIIFTRI UT1 differences.

Service. More information and data are in open anonymous access through `www.vniiftri.ru` and `ftp.vniiftri.ru`.

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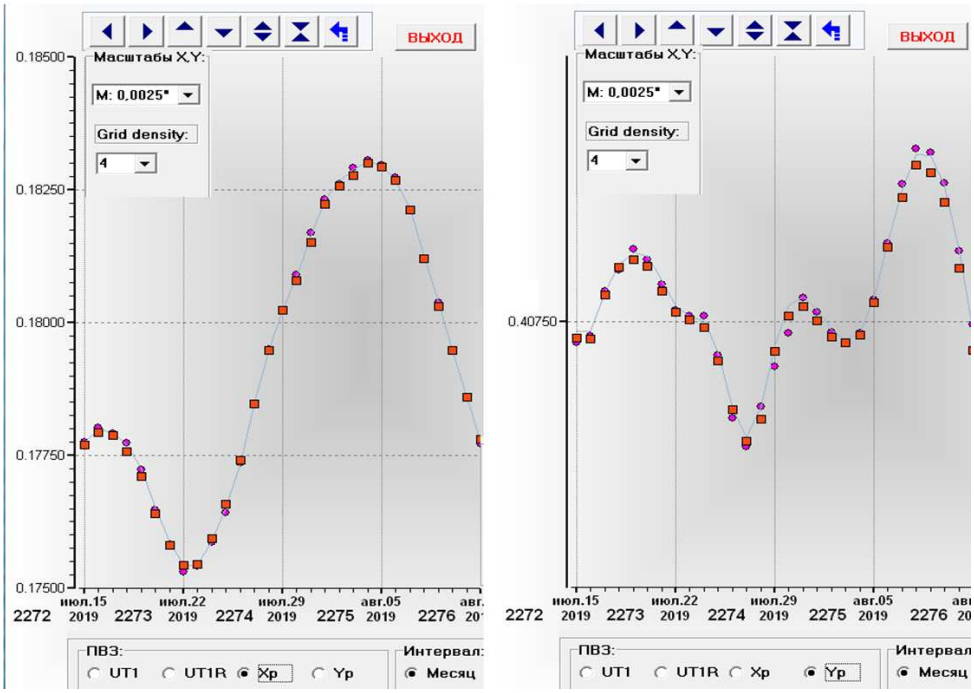

Figure 5: The Earth pole coordinates (trend removed). Solid line – USNO combination, squares – VNIIFTRI time raw combination, circles – VNIIFTRI SINEX combination results

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