Tsukuba VLBI Analysis Center

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Abstract The Tsukuba VLBI Analysis Center has been regularly performing near real time analysis of the weekend IVS Intensive (INT2) sessions using the *c5++* analysis software. This report summarizes the results of the INT2 analysis and some activities of the Analysis Center during 2019 and 2020.

1 Introduction

The Tsukuba VLBI Analysis Center, located in Tsukuba, Japan, is operated by the Geospatial Information Authority of Japan (GSI). A major role of the Analysis Center is to regularly analyze the weekend IVS Intensive (INT2) sessions and deliver the results to the IVS community. The analysis is performed in near real time and the estimate of UT1–UTC (=dUT1) is provided to the IVS community rapidly after the end of observation. A dedicated link to the SINET5 operated by the National Institute of Informatics (NII) and several process management programs make it possible to derive the solutions rapidly. Our products are utilized for more accurate dUT1 prediction by the U.S. Naval Observatory (USNO) at the IERS Rapid Service/Prediction Center, which is responsible for providing Earth orientation parameters on a rapid-turnaround basis, primarily for real-time users and others needing the highest quality for the Earth Orientation Parameter (EOP) information sooner than that available in the final EOP series [1, 2].

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2. Advanced Engineering Service Co.,Ltd.

2 Component Description

2.1 Analysis Software

An analysis software named *c5++*, which was jointly developed by Hitotsubashi University, the National Institute of Information and Communications Technology (NICT), and the Japan Aerospace Exploration Agency (JAXA) for various space geodetic techniques including SLR, GNSS, and VLBI, is officially used to estimate dUT1 in the regular INT2 sessions at the Analysis Center [3]. Currently, the analysis software is being updated by the institutions mentioned above and Onsala Space Observatory [4]. At present, the analysis center uses version 0.0.1 (rev 926) of the analysis software. The correlation and analysis management programs, so-called *rapid_* programs developed by GSI, can execute all processes from data transfer through analysis and provide the results consecutively and automatically. *Rapid_c5pp* runs *c5++* on outputs of the bandwidth synthesis process and estimates dUT1 to be delivered to the community quickly. Please refer to the report “Tsukuba VLBI Correlator” in this volume for further details of *rapid_* programs.

The Analysis Center creates the version 4 databases to submit to IVS using *νSolve* developed by NASA GSFC [5]. The version of *νSolve* is 0.6.3 as of December 2020. Until the end of August 2020, the Tsukuba VLBI Analysis Center was providing Mark III format databases in addition to vgosDB format databases based on requests from some Analysis Centers, but only vgosDB format databases have been provided since September 5, 2020, because there have been no more requests.

2.2 Analysis Center Hardware Capabilities

At the Analysis Center, *c5++* and *νSolve* are installed on several general purpose and commercially produced Linux computers to perform dUT1 analysis. The main analysis server has two 3-TB hard disk drives where the VLBI databases and necessary a priori files are stored. One is used as main storage and mirrored by the other regularly. We are planning to increase the storage capacities in the future.

3 Staff

The technical staff in the Tsukuba VLBI Analysis Center are:

- **Yu Takagi** — correlator/analysis chief, management.
- **Kyonosuke Hayashi** — correlator/analysis operator, coordination.
- **Tetsuya Hara** (AES) — correlator/analysis operator, software development.

4 Analysis Operations

4.1 Updates of the Analysis Environment

There were a few major updates of the analysis software and setting during this period.

- **Transition to ICRF3**

The Analysis Center had been conducting analysis with the ICRF2 source position catalog set for both *c5++* and *νSolve* since April 2010. Since ICRF3 was released in January 2019, the Analysis Center changed the source position catalog for *νSolve* from ICRF2 to ICRF3 in February 2019. For *c5++*, the catalog was changed in January 2020. In the INT2 analysis, we used ICRF3 starting with Q19054 for *νSolve* and with Q20025 for *c5++*.

- **Update of *c5++* Version**

The Analysis Center used version 0.0.1 (rev 907) of c5++ until January 2019, and updated the analysis software version twice between 2019 and 2020. First, we updated *c5++* to version 0.0.1 (rev 920) on January 22, 2020, because *c5++* began to support ICRF3 from version 0.0.1 (rev 918). For the INT2 analysis, this version was used from Q20025 to Q20138. The second update was to version 0.0.1 (rev 926) on May 23, 2020, because there were major updates regarding the available mapping functions from version 0.0.1 (rev 922) to version 0.0.1 (rev 924). We are using this version from Q20144 onward for the INT2 analysis.

- **Change mapping function**

In *c5++*, three mapping functions, VMF3, V3GR, and GPT3, provided by the Vienna University of Technology [6] have been available since version 0.0.1 (rev 922). The Analysis Center was using VMF1 as the mapping function, but with the update of *c5++* to version 0.0.1 (rev 926), we considered changing the mapping function to be used in the future to either VMF3 or V3GR. To investigate the effect of changing the mapping function, we compared the estimates of dUT1 for three different mapping functions of VMF1, VMF3, and V3GR, using the data of the INT2 sessions conducted from January 2019 to March 2020. Figure 1 shows the difference of dUT1 solutions using each mapping function from IERS EOP 14C04. The mean and standard deviation were 2.46 ± 20.22, 2.44 ± 20.20, and 1.14 ± 19.70 microseconds for VMF1, VMF3, and V3GR, respectively. Although the difference from IERS EOP 14C04 was slightly the smallest when V3GR was used, there was no significant difference in each dUT1 values estimated with the three mapping functions. Therefore, we have been using VMF3 as the mapping function of *c5++* since May 23, 2020, because it is easy to migrate from VMF1. We will continue to consider the adoption of V3GR.

4.2 Summary of UT1–UTC Results

Almost all of the weekend INT2 sessions were processed at the Analysis Center automatically in near real time using the *rapid_* programs. Table 1 summarizes the INT2 sessions analyzed by the Analysis Center in 2019 and 2020. The number of analyzed INT2 sessions was 99 and 97 in 2019 and 2020, respectively. The estimated dUT1 were submitted to the IVS Data Center as gsiint2c.eopi.

Ishioka (ISHIOKA) in Japan and Wettzell 20-m (WETTZELL) in Germany usually participate in the

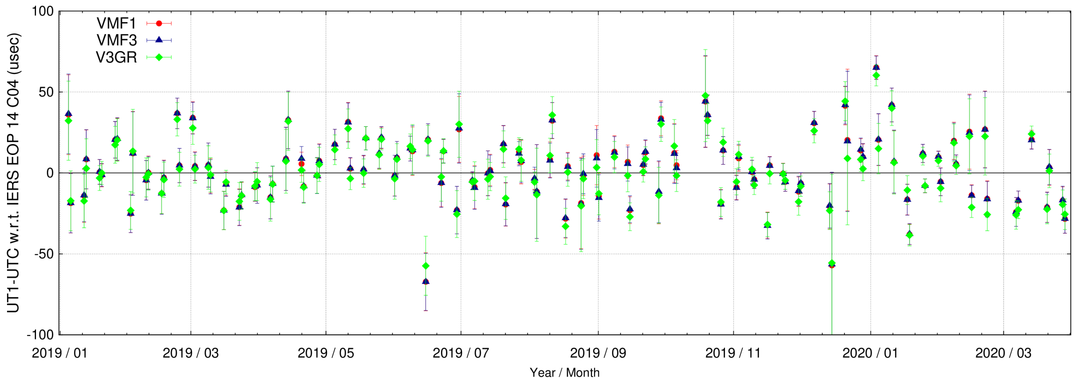

Fig. 1 The time series of the difference of dUT1 solution using each mapping function from IERS EOP 14C04. The data from the INT2 sessions conducted between January 2019 and March 2020 were used.

Table 1 Intensive sessions analyzed at the Tsukuba Analysis Center.

2019	Baseline	# of sessions	Ave. of dUT1 formal uncertainties
Intensive 2	IsWz	91	11.78 µsec
	IsNy	1	18.71 µsec
	MkWz	4	10.09 µsec
	KkWz	3	32.61 µsec
Total		99	12.44 µsec

2020	Baseline	# of sessions	Ave. of dUT1 formal uncertainties
Intensive 2	IsWz	29	9.21 µsec
	MkWz	43	8.19 µsec
	KkWz	25	10.05 µsec
Intensive 3	NyShWnWz	1	27.94 µsec
Total		98	9.28 µsec

INT2 sessions. When ISHIOKA was not available because of its VGOS period for a few months in a year or its mechanical trouble, either the VLBA antenna at Mauna Kea (MK-VLBA) or Kokee Park (KOKEE) in Hawaii, U.S., participated in the INT2 sessions as substitute of ISHIOKA. Ny-Ålesund (NYALES20) in Norway also filled in the absence of WETTZELL.

The averaged formal error for the ISHIOKA–WETTZELL baseline, the typical baseline of the INT2 session, was about ten microseconds, and the averaged formal errors for most baselines fell within the range of 20 microseconds (Table 1). Figure 2 shows the differences between dUT1 solutions for each baseline and IERS EOP 14C04 from January 2019 through December 2020. The IVS Intensive 3 (INT3) session

Table 2 Summary of automated processing results.

	2019	2020
# of sessions	99	97
Success in real time processing	72	74
– Ave. of Latency	40 min	1 hour 20 min
Failed in real time processing	27	23
– Data quality (outlier)	5	14
– *rapid_* programs failure	4	1
– Station or data transfer failure	18	8

observed on July 27, 2020, correlated at the Tsukuba VLBI Correlator, was also analyzed.

Table 2 outlines the results of the near real time processing of the INT2 sessions processed at the analysis center in 2019 to 2020. 72 out of 99 and 74 out of 97 sessions were successfully processed in near real time in 2019 and 2020, respectively. A total of 50 near real time processing failures were due to problems with the observation data or the observing stations. The average time it took to obtain the dUT1 estimation was about 40 minutes in 2019 and about 1 hour and 12 minutes in 2020. In particular, when the near real time processing was successful, the estimated values for dUT1 were delivered within approximately one hour for the ISHIOKA–WETTZELL baseline.

5 Outlook

We will continue to analyze the data of the IVS Intensive sessions and deliver dUT1 products in near real time. In addition, we will keep updating our automatic

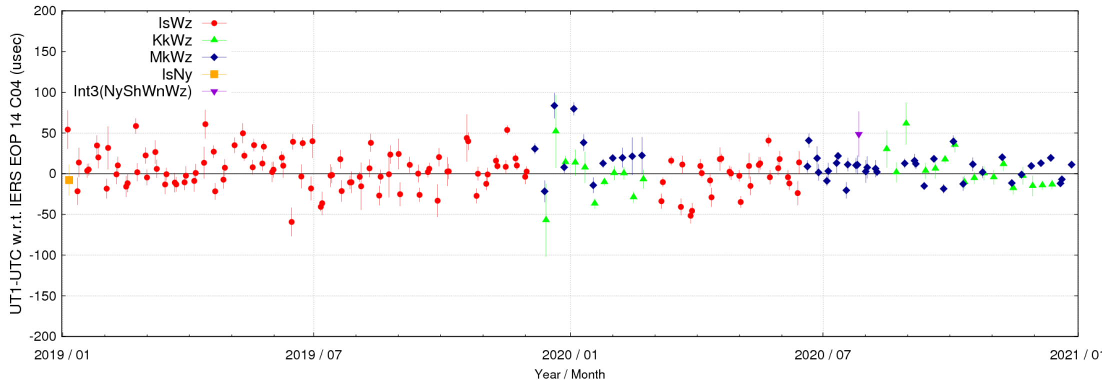

Fig. 2 The time series of UT1–UTC solutions obtained at the analysis center with respect to IERS EOP 14C04. Error bars are 1-σ formal uncertainties. Error bars are 1-σ formal uncertainties.

processing programs with the aim of improving the accuracy of dUT1 estimates and submitting more stable products.

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