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 (INT-2) sessions using *c5++* analysis software. This report summarizes the results of the INT-2 analysis and some activities of the Analysis Center during 2021 and 2022.

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 (INT-2) sessions and deliver the results to the community. The analysis is performed in near real-time, and the estimate of UT1-UTC (=dUT1) is provided to the community rapidly after the end of observing. A dedicated link to the SINET6 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) as the IERS Rapid Service/Prediction Center, which is responsible for providing Earth Orientation Parameters (EOP) on a rapid turnaround basis, primarily for real-time users and others needing the highest quality of the EOP information sooner than that available in the final EOP series [1, 2].

1. Geospatial Information Authority of Japan
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 INT-2 sessions at the Analysis Center [3]. Currently, the analysis software is updated by the institutions mentioned above and by the Onsala Space Observatory [4]. At present, the Analysis Center uses the 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 the 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 the *rapid_* programs.

The Analysis Center creates version 4 databases for submission to IVS using *νSolve* developed by NASA GSFC [5]. The version of *νSolve* is 0.6.3 as of December 2022.

2.2 Analysis Center Hardware Capabilities

At the Analysis Center, *c5++* and *vSolve* are installed on several general-purpose and commercially-produced Linux computers to perform dUT1 analysis. The main analysis server has two 10 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.

3 Staff

The technical staff members at the Tsukuba VLBI Analysis Center as of December 2022 are:

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

4 Analysis Operations

4.1 Updates of the Analysis Environment

- **New EOP File Format**

The IVS decided to update the EOP file format from version 2 to version 3. Following the decision, we modified our program so that the EOP file we provide, gsiint2c.eopi, is created in the new format. It is provided in the new file format from the processing of q22323 on November 19, 2022. In addition to the EOP file format, it was decided that the master file format and the name convention of the database would be changed from the beginning of 2023. We are now improving our programs so that they can handle these changes.

- **Hardware Update**

The Analysis Center hardware underwent a few minor updates during this period. First, we installed a new computer that has a more powerful CPU than the previous one. Second, the hard disk drive used to store the analysis results such as databases was updated to 10 TB, which enables us to store more results.

Table 1 INT-2 sessions analyzed at the Tsukuba Analysis Center in 2021 and 2022. Is, Mk, Wz and Kk represent ISHIOKA, MK-VLBA, WETTZELL, and KOKEE, respectively.

2021	Baseline	# of sessions	Ave. of dUT1 formal uncertainties
Intensive 2	IsMkWz	12	5.9 μsec
	MkWz	46	6.7 μsec
	IsWz	15	10.8 μsec
	KkWz	17	13.0 μsec
Total		90	8.5 μsec
2022	**Baseline**	**# of sessions**	**Ave. of dUT1 formal uncertainties**
Intensive 2	IsMkWz	35	7.5 μsec
	MkWz	62	7.0 μsec
	IsWz	3	21.0 μsec
Total		100	7.7 μsec

Table 2 Summary of automated processing results.

	2021	2022
# of sessions	90	100
Success in real-time processing	66	56
– Ave. of Latency	1 h 45 m	4 h 19 m
Failed in real time processing	24	44
– Data quality (outlier)	15	14
– *rapid_* programs failure	1	10
– Station or data transfer failure	8	20

4.2 Summary of UT1-UTC Results

All of the weekend INT-2 sessions were automatically processed at the Analysis Center in near real-time using the *rapid_* programs. The results for INT-2 sessions that were processed at the Analysis Center in 2021 and 2022 are summarized in Table 1. The results were submitted to the IVS Data Centers as gsiint2c.eopi. Since 2021, the VLBA antenna at Mauna Kea (MK-VLBA) in Hawaii, U. S., and the Wettzell 20-m station (WETTZELL) in Germany have participated mainly in the INT-2 sessions. The Ishioka station (ISHIOKA) in Japan also participated in INT-2 sessions while it was installing the S/X feed. When MK-VLBA and ISHIOKA were unavailable, Kokee Park (KOKEE) in

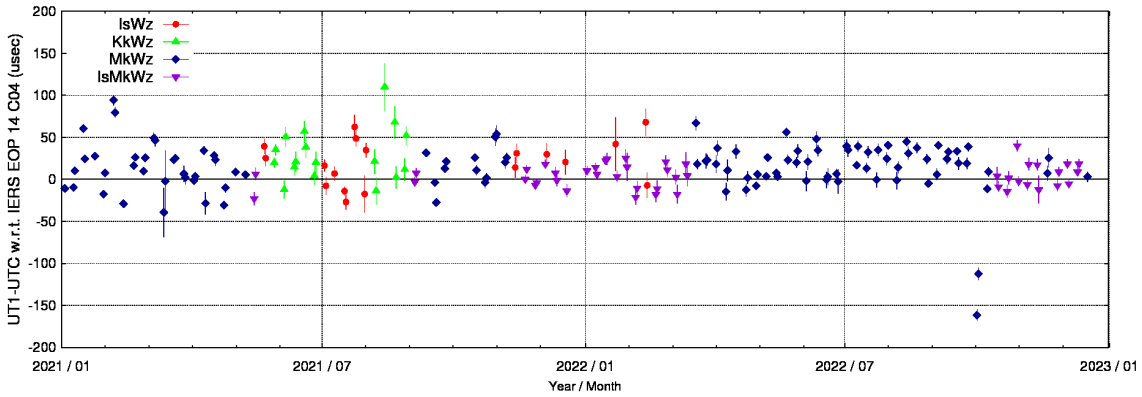

Fig. 1 The time series of UT1-UTC solutions obtained at the Analysis Center with respect to IERS EOP 14C04 from 2021 to 2022. Error bars represent 1-σ formal uncertainties.

Hawaii, U. S., replaced them. The average formal errors for total sessions were about 8 microseconds for both 2021 and 2022 (Table 1). It is also shown that the formal errors did not exceed 15 microseconds except in the sessions for the baseline ISHIOKA-WETTZELL in 2022, which were carried out only three times (Table 1). Figure 1 shows the difference of estimated dUT1s from the IERS EOP 14C04 from January 2021 through December 2022.

The results of near real-time processing of INT-2 sessions for 2021 and 2022 are outlined in Table 2. We successfully processed 66 sessions out of 90 sessions in near real-time in 2021, while 56 sessions out of 100 sessions succeeded in real-time processing in 2022. In 2022, we experienced some troubles, including the failure of data transfer and unexpected names for the data files. We created new programs to handle some of these problems. For the sessions processed in near real-time, data transfer took a longer time in 2022 than in 2021. This is the main reason why the latency exceeded four hours in 2022.

5 Outlook

We will continue to analyze the IVS S/X intensive sessions and provide dUT1 products in near real-time. In order to improve the accuracy of dUT1 estimates and to submit more stable products, we will keep updating our automatic processing programs.

References

1. Stamatakos, N., M. Davis, N. Shumate, and M. S. Carter, "Rapid Service/Prediction Centre", IERS Annual Report 2017, Edited by Wolfgang R. Dick and Daniela Thaller. International Earth Rotation and Reference Systems Service, Central Bureau. Frankfurt am Main: Verlag des Bundesamts für Kartographie und Geodäsie, ISBN 978-3-86482-131-8 (print version), pages 94–116, 2017.
2. Stamatakos, N., M. Davis, N. Shumate, and M. S. Carter, "Rapid Service/Prediction Centre", IERS Annual Report 2018, Edited by Wolfgang R. Dick and Daniela Thaller. International Earth Rotation and Reference Systems Service, Central Bureau. Frankfurt am Main: Verlag des Bundesamts für Kartographie und Geodäsie, ISBN 978-3-86482-136-8 (print version), pages 102–124, 2020.
3. Hobiger, T., T. Otsubo, M. Sekido, T. Gotoh, T. Kubooka, and H. Takiguchi, "Fully automated VLBI analysis with c5++ for ultra-rapid determination of UT1", Earth Planets Space, **62**, pages 933–937, 2010.
4. Haas, R., T. Hobiger, H.-G. Scherneck, N. Kareinen, G. Klopotek, P.-K. Diamantidis, and J. Strandberg, "Onsala Space Observatory – IVS Analysis Center Activities During 2017-2018", IVS 2017+2018 Biennial Report, Edited by K. L. Armstrong, K. D. Baver, and D. Behrend, NASA/TP-2020-219041, pages 234–238, 2020.
5. Bolotin, S., K. Baver, J. Gipson, D. Gordon, and D. MacMillan, "The First Release of νSolve", IVS 2012 General Meeting Proceedings, Edited by D. Behrend and K. D. Baver, NASA/CP-2012-217504, pages 222–226, 2012.