Tsukuba VLBI Analysis Center

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Abstract This report summarizes the activities of the Tsukuba VLBI Analysis Center during 2017 and 2018. The weekend IVS Intensive (INT-2) sessions were regularly analyzed in near real time using *c5++* analysis software.

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. It should be noted that a UT1–UTC (=dUT1) solution becomes available rapidly after the end of each observing session. 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) as the IERS Rapid Service/Prediction Centre, which is responsible for providing earth orientation parameters on a rapid turnaround basis, primarily for real-time users and others needing the highest quality EOP information sooner than that available in the final EOP series [1].

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2 Component Description

2.1 Analysis Software

An analysis software named *c5++*, which was jointly developed by Hitotsubashi University, National Institute of Information and Communications Technology (NICT), and Japan Aerospace Exploration Agency (JAXA) for various space geodetic techniques including SLR, GNSS, and VLBI, is officially used to provide dUT1 estimates in regular INT-2 sessions at the Analysis Center [2]. The current version of *c5++* is version 0.0.1 (rev. 907) as of December 2018.

The correlation and analysis management programs, so-called *rapid*_programs, developed by GSI can execute all processes from data transfer through analysis 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 about the *rapid*_programs.

The version 4 databases are created by using *νSolve* at the Analysis Center. In response to the transition of the database format from Mark III to vgosDb at the instruction of the IVS, vgosDb-compatible utilities developed by NASA GSFC (*vgosDbMake*, *vgosDbProcLogs*, and *vgosDbCalc*) were installed and incorporated into the ordinary procedure [3]. The current version of *νSolve* is version 0.6.3 as of December 2018. The Mark III format databases are also created by using *MK3TOOLS* instead of *vgosDbMake* and *vgosDbProcLogs* based on requests from a few Analysis Centers [4].

Table 1 Analysis Center hardware capabilities.

Number of servers	four for VLBI analysis (*c5++*, *νSolve* and *MK3TOOLS*)
Operating System	CentOS version 6.9, 7.5, and Red Hat Enterprise Linux 6.3
CPU	Intel Xeon X3360 @2.83GHz 4 cores 2 × Intel Xeon X5687 @3.60GHz 4 cores Intel Xeon E3-1270V2 @3.50GHz 4 cores 2 × Intel Xeon X5680 @3.33GHz 4 cores
Storage capacity	2 × 3 Tbytes

2.2 Analysis Center Hardware Capabilities

C5++, *νSolve* and *MK3TOOLS* are installed on several general-purpose and commercially-produced Linux computers (Table 1). Two 3-TB HDDs are used for storing VLBI databases and necessary a priori files. One is used as main storage and mirrored by the other regularly.

3 Staff

The technical staff of the Tsukuba VLBI Analysis Center are:

- **Takahiro Wakasugi**: correlator/analysis chief, management.
- **Michiko Umei**: correlator/analysis operator, coordination.
- **Tetsuya Hara** (AES): correlator/analysis operator, software development.

4 Analysis Operations

4.1 New Intensive Solution gsiint2c

IVS has started the INT-2 series on the Ishioka–Wettzell baseline in January 2017 in response to the retirement of the Tsukuba 32-m telescope at the end of 2016 after parallel operations for three months to secure the consistency of products. Taking this opportunity, the analysis center renewed some things in the procedure. The a priori station position and velocity were updated to ITRF2014 instead of VTRF2008. The position and velocity of Ishioka were estimated by a global solution calculated by GSI aligned with ITRF2014. The analysis software *c5++* was shifted from the beta version to the release version. This software update included the full compliance of geophysical models with the IERS Conventions 2010 and a new automatic ambiguity estimation strategy [5]. In addition, our correlation and analysis management programs were slightly modified for fully automated processing. The new dUT1 estimation results, called *gsiint2c*, has been released since 2017 to IVS Data Centers. The new solution is also available on our FTP site:

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ftp://ftp.spacegeodesy.go.jp/vlbi/
products/eopi/gsiint2c.eopi
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As described in Section 2.1, the *gsiint2c* solution has been delivered in near real time by fully automated processes from data transfer to analysis in the same way as the previous solution.

Table 2 Intensive sessions processed at the Tsukuba Analysis Center.

2017	Baseline	# of sessions	Ave. of dUT1 formal uncertainties
Intensive 2	IsWz	79	11.44 μsec
	IsWn	2	13.15 μsec
	KkWz	8	16.26 μsec
	ShWz	4	5.80 μsec
	KbWz	1	4.20 μsec
Intensive 3	IsNyWnWz	1	5.30 μsec
Total		95	11.51 μsec
2018	**Baseline**	**# of sessions**	**Ave. of dUT1 formal uncertainties**
Intensive 2	IsWz	59	11.69 μsec
	IsWn	2	15.15 μsec
	KkWz	18	19.08 μsec
	KkWn	1	13.30 μsec
	ShWz	4	27.85 μsec
	ShWn	1	26.30 μsec
	KbWz	2	10.25 μsec
Intensive 3	IsWnWz	1	7.70 μsec
Total		88	14.12 μsec

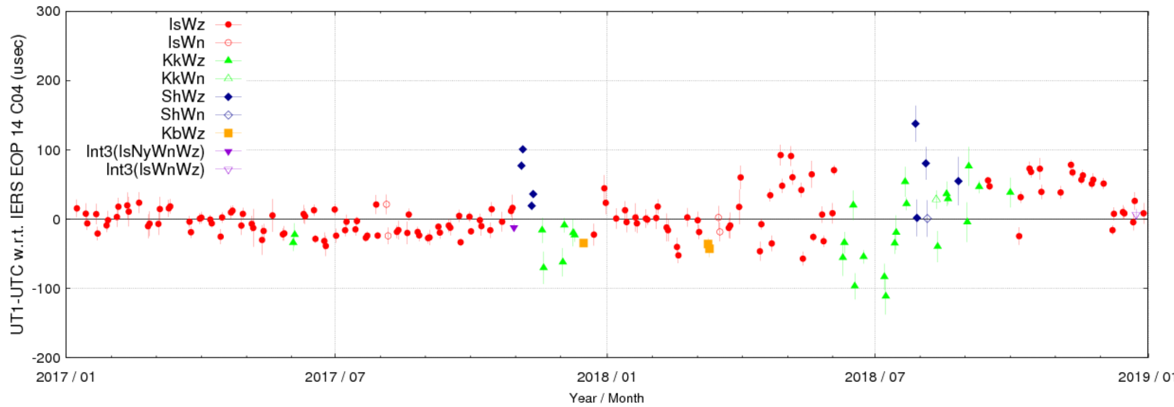

Fig. 1 Time series of UT1–UTC derived from IVS Intensive sessions with respect to IERS EOP 14 C04. Error bars are 1-σ formal uncertainties.

Table 3 Summary of automated processing results.

	2017	2018
# of sessions	95	88
Success in real time processing	49	61
– Average Latency	1 hour 15 min	1 hour 43 min
Failed in real time processing	46	27
– Data quality (outlier)	9	9
– *rapid*_programs failure	13	7
– Station or data transfer failure	24	11

4.2 Summary of UT1-UTC Results

All of the weekend Intensive series (INT-2) were analyzed at the analysis center automatically in near real time using the *rapid*_programs. The number of sessions processed in 2017 and 2018 are listed in Table 2. Ishioka in Japan and Wettzell 20-m in Germany have participated in INT-2 sessions usually. On the other hand, some telescopes such as Kokee Park in Hawaii, U.S., Sheshan in China, or Kashima 34-m in Japan were involved when Ishioka was not available during the VGOS test period for a few months a year. The 13.2-m Wettzell North Telescope also filled in occasionally during the absence of Wettzell 20 m. In addition, a few INT-3 sessions on Monday correlated at the Tsukuba VLBI Correlator were analyzed too.

The automated programs succeeded in near real time processing in 49 out of 95 sessions and 61 out of 88 sessions in 2017 and 2018, respectively (Table 3). Notably, a new automatic ambiguity estimation strategy implemented with the update of *c5++* worked well, resulting in near real time processing in eight and seven sessions in 2017 and 2018, respectively. The formal errors for the estimated dUT1 were also described in Table 2. The average formal error for the Ishioka–Wettzell baseline, which is the typical baseline of INT-2, was about 11 microseconds, and the average formal error for most baselines fell within the range of 20 microseconds. Figure 1 shows the differences between dUT1 solutions with each baseline and IERS EOP 14 C04 from January 2017 through December 2018. Estimated dUT1 became available within two hours after the end of the observation typically.

On the other hand, the automated analysis processing failed at times due to some sort of problem in the observation especially in 2017. The main reason for this is considered to be the initial failure. As described in Section 4.1, the Ishioka station became a regular participating station in 2017. Moreover, some stations such as Kokee Park or Sheshan have begun to be involved in INT-2 too. The imperfection in *rapid*_programs as well as procedures at station ends caused most of the failures. These errors considerably decreased in 2018. Unsuccessful runs of the automated processing using the *rapid*_programs in 2018 were mainly due to the data format conversion before correlation. To deal with this problem, the *rapid*_programs were modified so as to handle various data formats such as VDIF and Mark 5B without format conversion, and incorporated in automated procedure since December 2018 (please refer to the report "Tsukuba VLBI Correlator" in this volume).

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 automated programs to secure more stable operation on various combinations of baseline or multiple baseline sessions.

References

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