Tsukuba VLBI Analysis Center

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Abstract This report summarizes the activities of the Tsukuba VLBI Analysis Center during 2015 and 2016. The weekend IVS Intensive (INT2) sessions were regularly analyzed using the *c5++* analysis software.

1 Introduction

The Tsukuba VLBI Analysis Center, located in Tsukuba, Japan, is operated by the Geospatial Information Authority of Japan (GSI). One of our major roles as an Operational Analysis Center is to regularly analyze the weekend IVS Intensive (INT2) sessions using the fully automated VLBI analysis software *c5++* developed by the National Institute of Information and Communications Technology (NICT) [1]. It should be noted that a UT1–UTC (= dUT1) solution becomes available within a few minutes after the end of the last scan of a session. A 10 Gbps 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. In addition, we started the Ishioka–Wettzell baseline observations called Q-Intensives from October 2016 in order to validate dUT1 solutions of the new baseline.

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2 Component Description

2.1 Analysis Software

C5++, which is an analysis software for space geodesy including SLR, GNSS, and VLBI, is officially used to provide a dUT1 solution in regular INT2 sessions.

Calc/Solve has been in use throughout from the early days of VLBI work at GSI. It is used for the analysis of Japanese domestic VLBI observations (JADE) and Asia-Oceania VLBI Group for Geodesy and Astrometry (AOV) sessions in its interactive mode and for global analysis in batch mode. In 2016, we confirmed that *vSolve* released by the GSFC VLBI group worked well as a substitute for the legacy user interface of the interactive mode of *Solve*. We will use it for regular sessions starting in 2017.

2.2 Analysis Center Hardware Capabilities

c5++, *Calc/Solve*, and *vSolve* are installed on several general purpose and commercially produced Linux computers (Table 1). Two 3 TB HDDs are used for storing many VLBI data files such as Mark III databases. One is used as main storage and mirrored by the other regularly.

3 Staff

The technical staff of the Tsukuba Analysis Center are:

Table 1 Analysis Center hardware capabilities.

Number of servers	five for VLBI analysis (*c5++*, *Calc/Solve*, and *vSolve*)
Operating System	CentOS version 5.4, 5.5, 6.5, and Red Hat Enterprise Linux 6.3
CPU	Intel Xeon X3360 @2.83GHz quad CPU, Intel Xeon X5687 @3.60GHz quad CPU x 2 Intel Xeon E3-1270V2 @3.50GHz quad CPU
Storage capacity	3 Tbytes x 2

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

4 Analysis Operations

4.1 IVS Intensive for UT1-UTC

There were 104 and 106 IVS Intensive sessions analyzed at the Tsukuba Analysis Center in 2015 and 2016, respectively. The dUT1 results were submitted as gsiint2b.eopi to the IVS Data Center (Table 2). Only the dUT1 parameter was estimated with station positions fixed to a priori values. For the Tsukuba station after the 2011 Off-the-Pacific-Coast-of-Tohoku Earthquake, the position correction of the non-linear postseismic motion provided by NASA/GSFC was used. The Tsukuba–Wettzell baseline and several other baselines were analyzed. The observed data at Wettzell are e-transferred to the Tsukuba Correlator in near real-time with the Tsunami UDP protocol. The correlated data are rapidly analyzed by *c5++* as soon as all of the correlator outputs are available, and then a dUT1 solution is derived and submitted. The dUT1 solution becomes available at the IVS Data Center immediately after the session. The processes from data transfer to submission of the solution are fully automated and done by unmanned operation.

Table 2 Intensive sessions analyzed at the Tsukuba Analysis Center.

2015	Baseline	# of sessions	Average of dUT1 sigma
Intensive 2	TsWz	99	7.04 µsec
	KbWz	2	14.00 µsec
Intensive 3	NyShTsWnWz	1	4.92 µsec
	NyTsWnWz	2	5.93 µsec
Total		104	7.13 µsec
2016	**Baseline**	**# of sessions**	**Average of dUT1 sigma**
Intensive 2	TsWz	100	8.50 µsec
	IsWz	27	10.12 µsec
Total		115	8.84 µsec

Since 42 out of 199 Tsukuba–Wettzell baseline analyses had some sort of problem in the observed data or trouble at the stations, the automated analyses failed. In the other 157 sessions, we succeeded in the rapid analysis with low latency. Figure 1 shows the cumulative distribution of 103 Tsukuba–Wettzell sessions from January 2015 to April 2016 with respect to the latency within which dUT1 solutions of the sessions were derived. About 90% of them completed analysis within four minutes after the end of the last scan, and all of them completed within six and half minutes. Though the latency increased slightly because of the decrease of the transfer rate caused by the replacement of a PC in Wettzell after May 2016, we still keep low-latency analysis completion, i.e., 80% of sessions completed within 15 minutes.

The ending time of IVS INT2 sessions is 8:30 UT on every Saturday and Sunday. Thus, the dUT1 solution is available for users before 9:00 UT as an IVS product. 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.

In the last quarter of 2015, GSI analyzed three INT3 (Monday morning in UT) sessions instead of the Bonn correlator due to its maintenance. This was the first time for Tsukuba Analysis Center in four years to process multi-baseline Intensive sessions. Our automated processing software was given the capability of multi-

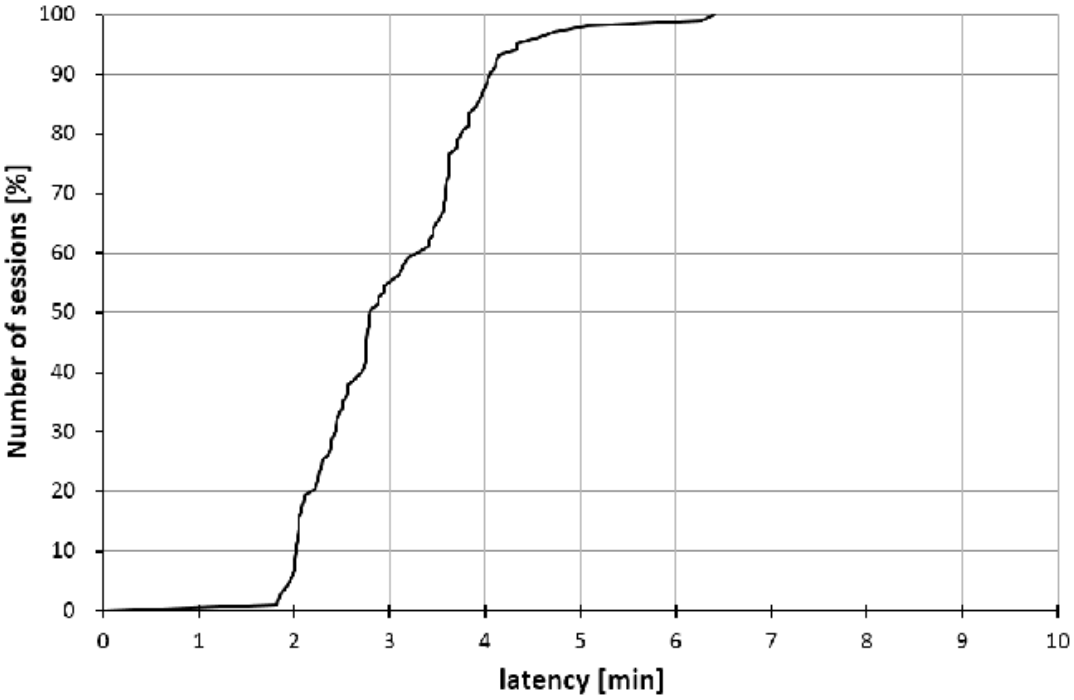

Fig. 1 The cumulative distribution of 103 Tsukuba–Wettzell sessions from January 2015 to April 2016 with respect to the latency within which dUT1 solutions of the sessions were derived.

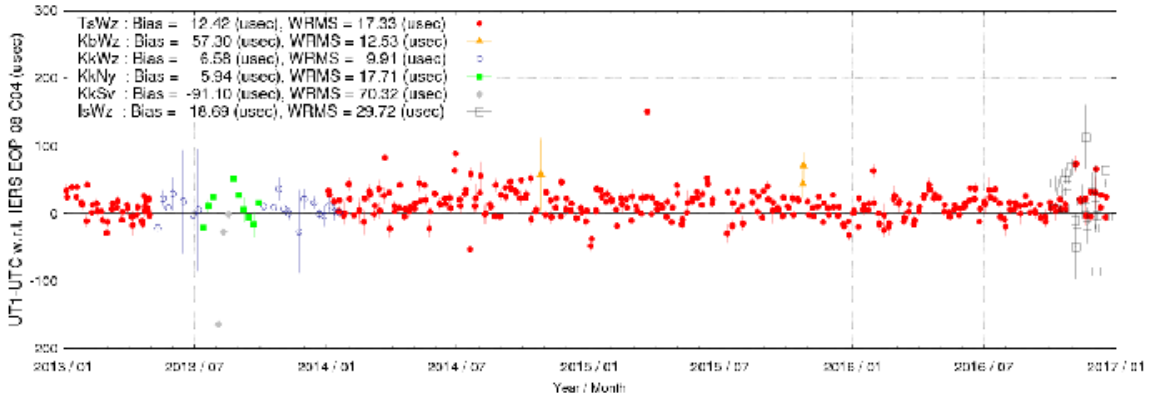

Fig. 2 The time series of UT1–UTC derived from IVS Intensives with respect to IERS EOP 08 C04. Error bars are 1 σ formal uncertainties.

baseline processing with only slight modifications, and the processing ended successfully.

Figure 2 shows the differences between the dUT1 solutions of each Intensive baseline and IERS EOP 08 C04 from January 2013 through December 2016.

4.2 IVS Intensive with Ishioka

IVS started the Ishioka–Wettzell baseline observations called Q-Intensives from October 2016 in response to ceasing operations of Tsukuba at the end of 2016. The Q-Intensives were also processed by GSI. There were some steps to establish the analysis process of this new baseline. We calculated the station coordinates of Ishioka by using the relative position to Tsukuba estimated from more than forty 24-h sessions. In conjunction with this new baseline solution, we updated the analysis software *c5++* from beta version to the release version with a new automatic ambiguity estimation strategy [2]. In addition to this, we slightly modified our correlation and analysis management programs for fully automated processing (refer to the report "Tsukuba VLBI Correlator" in this volume). Thirty-three Q-Intensive sessions were performed from October to December in 2016 in addition to the regular Tsukuba–Wettzell Intensive sessions. We started to release our new dUT1 results as gsiint2c.eopi to the IVS Data Center from the beginning of 2017.

5 Outlook

We will continue to analyze the data of the IVS INT2 sessions and submit dUT1 products with a low latency. In addition, we will try to modify our analysis process to obtain more precise results including compatibility with ITRF2014.

References

1. Hobiger, T., et al.: Fully automated VLBI analysis with c5++ for ultra-rapid determination of UT1, *Earth Planets Space*, **62**, 933-937, 2010.
2. Kareinen, N., et al.: Automated ambiguity estimation for VLBI Intensive sessions using K1-norm, *Journal of Geodynamics*, **102**, 39-46, 2016.