Tsukuba VLBI Analysis Center

Shinobu Kurihara [1], Tetsuya Hara [1,2]

Abstract This report summarizes the activities of the Tsukuba VLBI Analysis Center during 2014. The weekend IVS Intensive (INT2) sessions were regularly analyzed using *c5++* analysis software. Several ultra-rapid dUT1 experiments were implemented in association with Onsala, Hobart, and HartRAO.

1 Introduction

The Tsukuba VLBI Analysis Center, located in Tsukuba, Japan, is hosted and 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 the UT1-UTC (= dUT1) solution becomes available within a few minutes after the end of the last scan of the session. A 10 Gbps dedicated link to the SINET4 operated by the National Institute of Informatics (NII) and several process management programs make it possible to derive a solution rapidly. The ultra-rapid dUT1 experiments after some regular IVS 24-hour sessions and CONT14 sessions were implemented in 2014.

1. Geospatial Information Authority of Japan
2. Advanced Engineering Service Co., Ltd.

2 Component Description

2.1 Analysis Softwares

c5++, which is analysis software for space geodesy including SLR, GNSS, and VLBI, is officially used to provide a dUT1 solution from a regular INT2 session.

Calc/Solve has been in continuous use since the early days of VLBI work at GSI. It is used for the analysis of JADE, which is the Japanese domestic observation for geodesy, in its interactive mode and for global analysis in the batch mode. In June, we installed *ν*Solve released by the GSFC VLBI group. It has been working well as a substitute for the legacy user interface of the interactive mode of Solve.

VieVS, developed by the Institute of Geodesy and Geophysics (IGG) at the Vienna University of Technology, is also installed at the Tsukuba Analysis Center [2].

2.2 Analysis Center Hardware Capabilities

c5++, *Calc/Solve*, and *VieVS* are installed on several general-purpose and commercially-produced Linux computers (Table 1). Individual RAIDs are mounted on each computer for storing many VLBI data files such as Mark III databases.

3 Staff

The technical staff at the Tsukuba Analysis Center are:

Table 1 Analysis Center Hardware Capabilities.

Number of servers	six for VLBI analysis (*c5++*, *Calc/Solve*, and *VieVS*)
Operating System	CentOS version 5.4, 5.5, 6.5, and Red Hat Enterprise Linux 6.3
CPU	Intel Xeon @3.80GHz CPU x 2, Intel Xeon 5160 @3.00GHz dual CPU x 2, Intel Xeon X3360 @2.83GHz quad CPU, Intel Xeon X5687 @3.60GHz quad CPU x 2 Intel Xeon E3-1270V2 @3.50GHz quad CPU
Total storage capacity	individual RAIDs: 5.49 Tbytes in total

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

4 Analysis Operations

4.1 IVS Intensive for UT1-UTC

106 IVS Intensive sessions were analyzed at the Tsukuba Analysis Center, and 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. For the Tsukuba station after the 2011 Tohoku Earthquake, the position correcting its non-linear post-seismic motion provided by NASA/GSFC was used. The Tsukuba–Wettzell baseline and several other baselines were analyzed. The observed data at Wettzell is e-transferred to the Tsukuba Correlator in near real-time with the Tsunami UDP protocol. The correlated data is rapidly analyzed by *c5++* as soon as all of the correlator output comes in, and then a dUT1 solution is derived and submitted. The dUT1 solution becomes available at the IVS Data Center just after the session. The processes from data transfer through the submission of the solution are fully automated and done by unmanned operation. Since 19 out of the 101 Tsukuba–Wettzell baseline analyses had some sort of problem in the observed data or trouble at the stations, the automated analyses for those sessions failed. In the other 82 sessions, we succeeded in the rapid analysis with low latency, and 90% of them completed analysis within ten minutes after the end of the last scan (Figure 1). The end time of the IVS-INT2 sessions is 8:30 UT on every Saturday and Sunday. Thus, the dUT1 solution is available at the latest before 9 a.m. for users 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.

Table 2 Intensive sessions analyzed at the Tsukuba Analysis Center.

	Baseline	# of sessions	Average of dUT1 sigma
Intensive 2	TsWz	101	9.3 μsec
	KkWz	3	12.7 μsec
	KbWz	2	28.3 μsec
Total		106	9.7 μsec

Figure 2 shows the differences between the dUT1 solutions of each Intensive baseline and IERS EOP 08 C04 from January 2013 through December 2014.

4.2 Ultra-Rapid dUT1 Experiment

This experiment started in 2007 as a joint project of Japan (Tsukuba and Kashima) and Fennoscandia (Onsala and Metsähovi). It aims to derive a consecutive time series of dUT1 (or full set of EOP) as soon as possible. The observed data is sent in real-time via the international optical fiber backbone to Tsukuba where the data is correlated and analyzed. *c5++* is used in the whole analysis. Nowadays four countries — Japan, Sweden, Australia, and South Africa — are involved in association with Onsala, Hobart, and HartRAO.

In 2014, four regular IVS-R1 sessions and one R&D session were processed with the ultra-rapid mode (Table 3). Additionally, we operated the CONT14

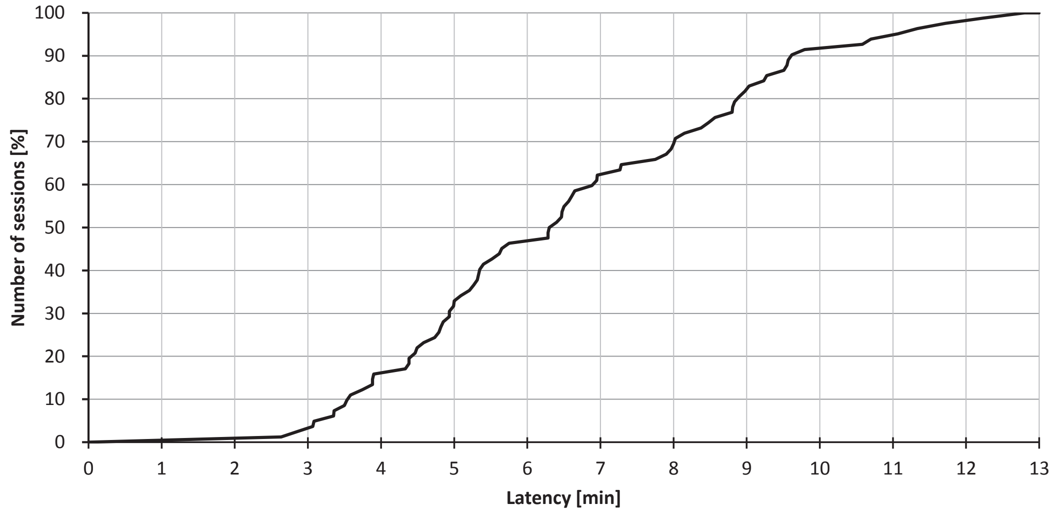

Fig. 1 Latency–number of sessions as % of 82 Tsukuba-Wettzell sessions. 19 sessions with some sort of trouble during the session are excluded.

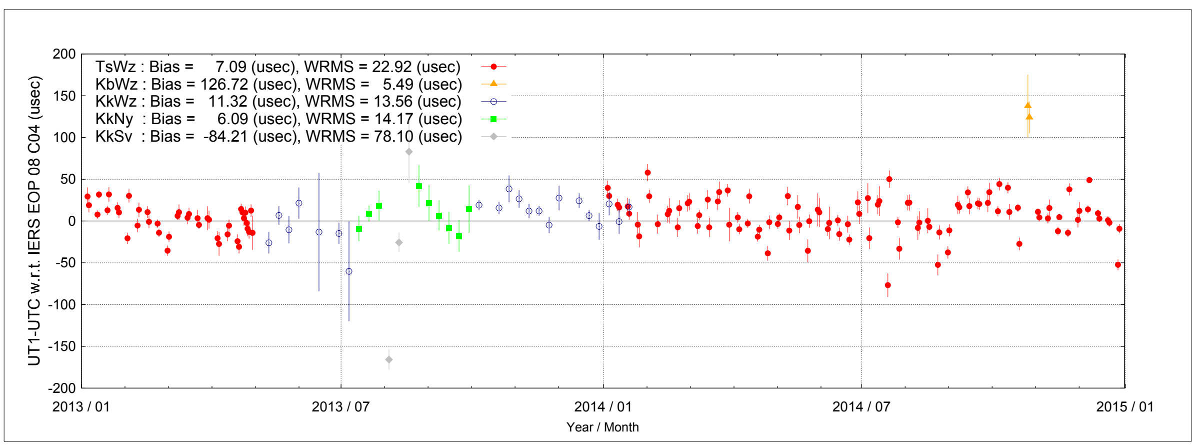

Fig. 2 The time series of UT1-UTC derived from IVS Intensive with respect to IERS EOP 08 C04. Error bars are 1 σ formal uncertainties.

campaign with the ultra-rapid processing for the Onsala–Tsukuba baseline. The Onsala data were e-transferred in real-time to the Tsukuba correlator using the Tsunami protocol. The data were correlated with the corresponding data from the Tsukuba station in near real-time, followed by a near real-time analysis to determine dUT1. One dUT1 value was estimated from the dataset of correlator outputs in a three-hour period. When a new correlator output comes in, the three-hour analysis period shifts forward and the oldest data out of the period are left out, and then a new analysis is performed. The analysis strategy is called "sliding window" approach. As a result, we could obtain a time series of dUT1 that is produced during the ongoing session with very low latency through 15 days. The average of the latency through 15 days was 6 min 18 sec. Figure 3 shows the estimated time series of dUT1, and Figure 4 shows differences between estimated dUT1 and IERS Rapid Prediction.

5 Outlook

We will continue to analyze the data of the IVS-INT2 sessions and submit dUT1 products with a low latency.

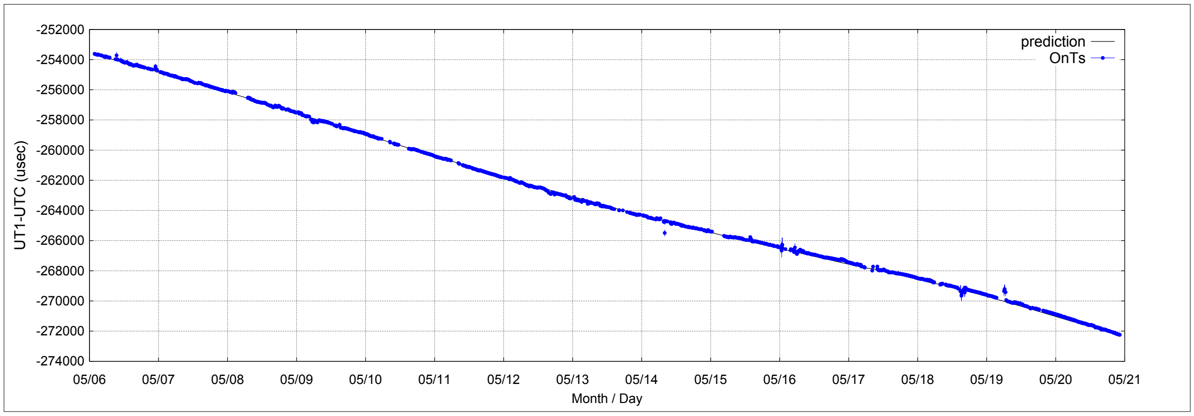

Fig. 3 The time series of UT1-UTC derived from the Onsala–Tsukuba baseline from IVS-CONT14 ultra-rapid processing with the prediction (Rapid Service/Prediction of Earth Orientation, finals2000A.daily).

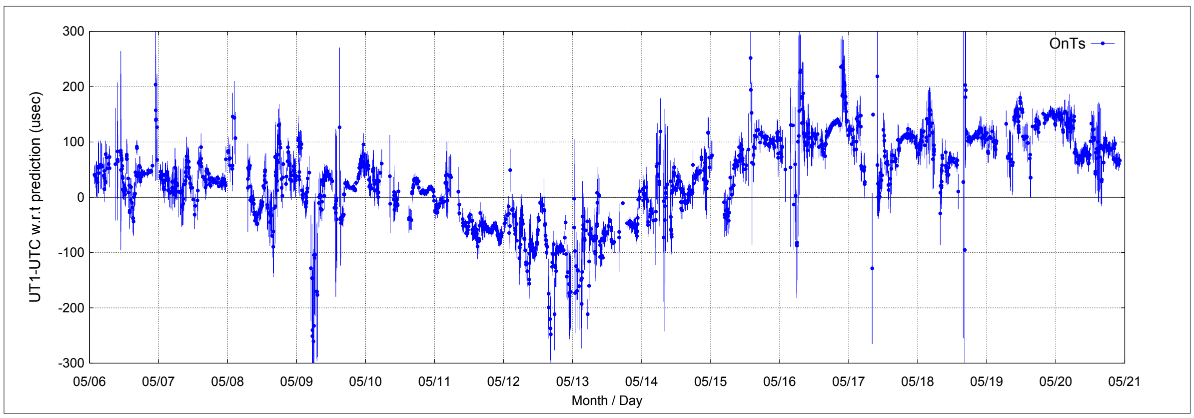

Fig. 4 Residuals of UT1-UTC with respect to the prediction (Rapid Service/Prediction of Earth Orientation, finals2000A.daily).

Table 3 The ultra-rapid experiments in 2014. All experiments were processed after the regular IVS sessions.

Exper.	Date	Time	Dur.	Stations	#obs. (skd)	#obs. (cor)
R1624	Feb 10	17:00	24	HtOnTs	287	275
RD1402	Mar 26	18:00	24	HbHtOnTs	244	278
R1631	Mar 31	17:00	24	OnTs	201	201
R1632	Apr 07	17:00	24	OnTs	191	191
CONT14	May 06	00:00	360	OnTs	3262	3009
R1657	Oct 13	17:00	24	HbHtOnTs	328	86

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. Böhm, J., et al.: The New Vienna VLBI Software VieVS, In Proceedings of IAG Scientific Assembly 2009, *International Association of Geodesy Symposia Series*, **136**, edited by S. Kenyon, M. C. Pacino, and U. Marti, doi: 10.1007/978-3-642-20338-1_126, 1007-1011, 2012.