Tsukuba VLBI Analysis Center

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Abstract This report summarizes the activities of the Tsukuba VLBI Analysis Center during 2013. The weekend IVS Intensive (INT2) sessions were regularly analyzed using *c5++* analysis software. Several ultra-rapid EOP experiments were implemented in association with Onsala, Hobart, and HartRAO.

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 us 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. Other than that, the ultra-rapid EOP experiments behind 14 regular IVS 24-hour sessions and three dedicated ultra-rapid experiments were implemented in 2013.

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

2 Component Description

2.1 Fully Automated VLBI Analysis Software c5++

c5++, which is an analysis software for space geodesy including SLR, GNSS, and VLBI, has been undergoing several modifications and updates by NICT and was installed on a host at the Tsukuba Analysis Center in the summer of 2012. In April 2013, we officially started to use *c5++* and to provide a dUT1 solution in the regular INT2 session. *C5++* supports flexible parameterization (X-pole, Y-pole, dUT1, nutation, station clocks, and troposphere) and SINEX input/output with covariance matrix. Therefore it is also used in the ultra-rapid EOP experiments (see Section 4.2).

2.2 Calc/Solve

Calc/Solve has been in use throughout from the early days of VLBI work in 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, which is for the purpose of our internal use, not for the IVS products as an Analysis Center.

2.3 Potential to Use VieVS

VieVS, developed by the Institute of Geodesy and Geophysics (IGG) of the Vienna University of Technol-

Table 1 Analysis Center Hardware Capabilities.

Number of servers	4 for VLBI analysis (*c5++*, *Calc/Solve*, and *VieVS*)
Operating System	CentOS version 5.4, 5.5, or 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
Total storage capacity	individual RAIDs: 2.79 Tbytes in total

ogy, has already been installed in the Tsukuba Analysis Center [2]. But it has not been operational yet. *VieVS* is quite interesting VLBI analysis software, having some unique features that are not seen in other software. We would like to start to use it soon and to utilize the features for our analysis work.

2.4 Analysis Center Hardware Capabilities

Both *c5++* and *Calc/Solve* are installed on several general-purpose and commercially-produced Linux computers (Table 1). MATLAB as a platform for *VieVS* is also available on a host. Individual RAIDs are mounted on each host for storing a lot of VLBI data files such as Mark III databases.

3 Staff

The technical staff in the Tsukuba Analysis Center are

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

4 Analysis Operations

4.1 IVS Intensive for UT1-UTC

72 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.

In 2013, the Tsukuba—Wettzell baseline and several other baselines were analyzed. The observed data at Wettzell is transferred to the Tsukuba Correlator in real-time with the VDIF/SUDP protocol. The correlated data is rapidly analyzed by *c5++* as soon as all the correlator outputs come in, and then a dUT1 solution is derived. Figure 1 shows that 90% of the total sessions complete analysis within five minutes after the end of the last scan. The end time of IVS-INT2 session is 8:30 UT on every Saturday and Sunday. Thus, the dUT1 solution is available at latest by 8:40. This is really an advantage of the Tsukuba Analysis Center. The eopi file, a product of Intensive analysis from the Analysis Center, is submitted immediately after the analysis and becomes accessible to users as an IVS product. The whole process of work from data transfer through submission of products is automated. 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 case of Kokee baselines, because the observed data at Kokee was transferred via USNO, it took a few hours to derive a solution.

Table 2 Intensive sessions analyzed at the Tsukuba Analysis Center.

	Baseline	# of sessions	Average of dUT1 sigma
Intensive 1	TsWz	7	9.7 μsec
Intensive 2	TsWz	34	8.1 μsec
	KkWz	19	14.6 μsec
	KkNy	9	17.3 μsec
	KkSv	3	19.9 μsec
Total		72	11.6 μsec

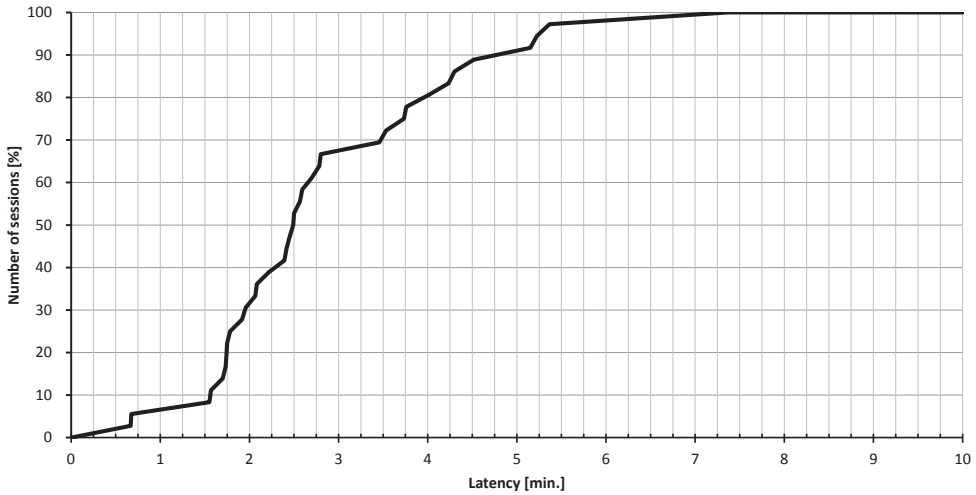

Fig. 1 Latency–number of sessions as % of 36 Tsukuba-Wettzell sessions. Five sessions with some sort of trouble during the session are excluded.

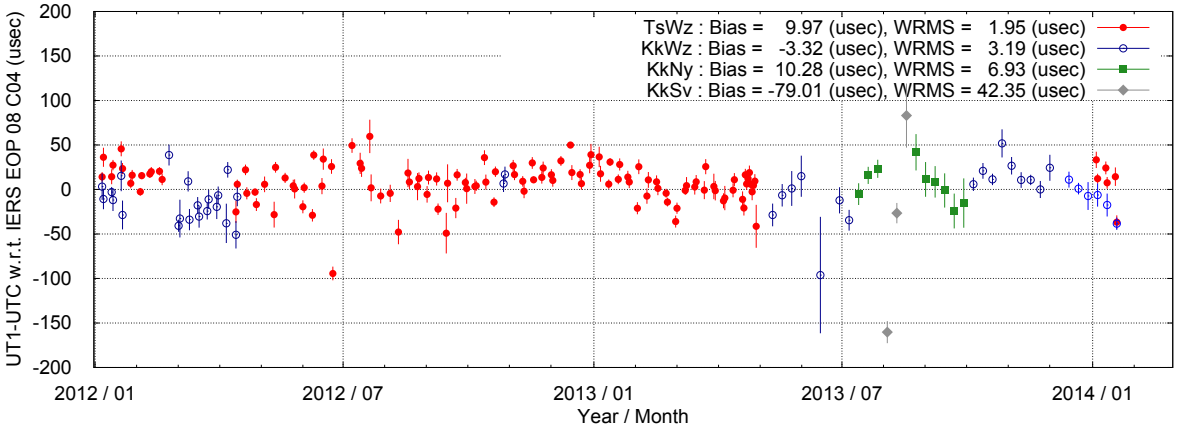

Fig. 2 The time series of UT1-UTC derived from IVS Intensive w.r.t. IERS EOP 08 C04. Error bars are 1 σ formal uncertainties.

Figure 2 shows the differences between the dUT1 solutions of each Intensive baseline and IERS EOP 08 C04 from January 2012 through January 2014.

4.2 Ultra-Rapid EOP Experiment

This session 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 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 2013, three ultra-rapid EOP experiments with dedicated schedules were conducted (Table 3). The first session UR1301 with four stations — Hobart, HartRAO, Onsala, and Tsukuba — in January lasted for 61 hours without any major failures, and polar motion and dUT1 were determined ultra-rapidly during the ongoing experiment. The second experiment UR1302 in February was also

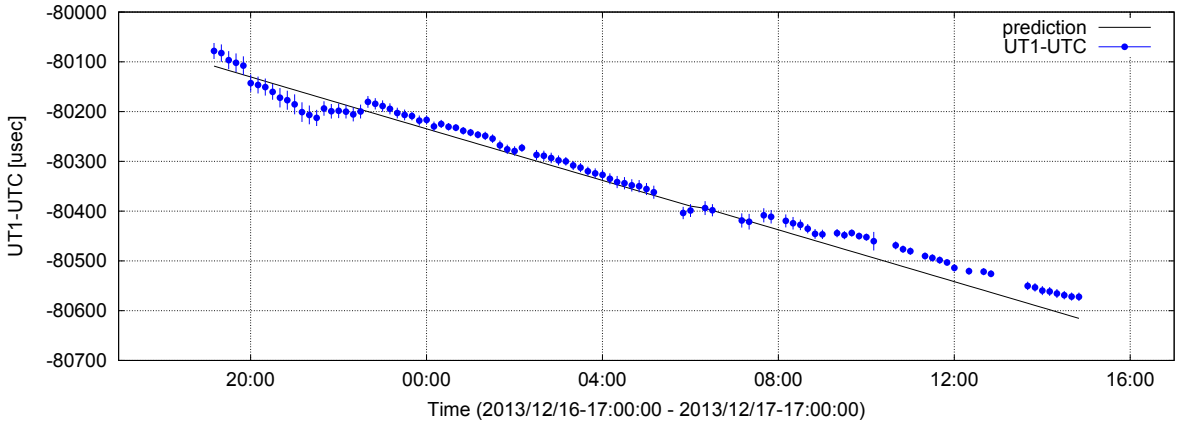

Fig. 3 The time series of UT1-UTC derived from the Onsala–Tsukuba baseline from IVS-R1616 ultra-rapid processing with the prediction (Rapid Service/Prediction of Earth Orientation, finals2000A.daily).

successful with three stations — Hobart, HartRAO, and Tsukuba.

In addition, 14 regular IVS 24-hour sessions that involved at least two stations out of Hobart, HartRAO, Onsala, and Tsukuba were also operated with the ultra-rapid processing. The sessions are listed in Table 3. Six of them were originally scheduled with three of the stations. But a fourth station was added to them via the tag-along function of SKED, and these six sessions observed a four-station/six-baseline network. Two experiments in December with one baseline, Onsala—Tsukuba, were completed without even any minor failures, and a dUT1 time series was produced in near real-time. Figure 3 shows the time series of dUT1 from IVS-R1616 ultra-rapid processing.

5 Outlook

We will continue to analyze the data of the IVS-INT2 sessions and submit dUT1 products with a low latency. CONT14 planned for May 2014 is a good opportunity to conduct the 15-day continuous ultra-rapid processing. And we might start to use *VieVS* in part of our analysis work.

Table 3 The ultra-rapid experiments in 2013. "*" means the station is not included in the original schedule but added by SKED tag-along.

Exper.	Date	Time	Dur.	Stations	#obs. (skd)	#obs. (cor)
with dedicated schedule						
UR1301	Jan 30	18:00	61	HbHtOnTs	1467	1326
UR1302	Feb 05	17:30	48.5	HbHtTs	943	815
UR1303	Dec 05	18:30	24	OnTs	611	606
behind IVS 24-hr schedule						
R1569	Jan 22	17:00	24	HbHhOnTs	541	539
R1570	Jan 28	17:00	24	HhOnTs	309	297
RD1301	Jan 29	17:30	24	HhOnTsHb*	394	392
R1573	Feb 18	17:00	24	HbOnTsHt*	565	513
T2088	Feb 19	17:30	24	HhOnTsHb*	275	247
R1579	Apr 02	17:00	24	HhOnTs	293	276
R1580	Apr 08	17:00	24	HtOnTsHb*	432	229
RD1302	Apr 09	17:30	24	HhOnTsHb*	482	-
R1582	Apr 22	17:00	24	HhOnTsHb*	348	332
R1592	Jul 01	17:00	24	HbHhOn	122	114
R1598	Aug 12	17:00	24	HbHhHtOn	323	262
RD1306	Aug 21	18:00	24	HoHhOn	140	110
R1615	Dec 09	17:00	24	OnTs	171	171
R1616	Dec 16	17:00	24	OnTs	196	195

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.