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Strategies for Improving the IVS-INT01 UT1 Estimates

Karen Baver, John Gipson

NVI, Inc./NASA Goddard Space Flight Center, Greenbelt, MD, 20771
Contact author: Karen Baver, e-mail: karen.d.baver@nasa.gov

Abstract

We discuss an alternative scheduling strategy for the IVS-INT01 sessions and demonstrate that it is more robust and produces lower formal errors than the strategy used for the operational Intensives.

1. Introduction

The primary purpose of the IVS-INT01 sessions is the estimation of UT1. Improving the accuracy and the precision of the UT1 estimates is an important goal in the scheduling of these sessions. In 2009 the GSFC VLBI Analysis Center requested and received the use of four IVS R&D sessions, RD0907 through RD0910, for the evaluation of a new strategy for scheduling the IVS-INT01 sessions. In this paper we present some preliminary results from our analysis of RD0907 through RD0909, and we discuss future work.

2. Labeling the Intensives

In this paper we consider different kinds of one-hour sessions observing the Kokee—Wettzell baseline. We will refer to all of these sessions as Intensives. In order to distinguish them, we need a simple way of labeling them. Where necessary, we will distinguish them by type (USNO, STND, or TEST) and/or by Greenwich Sidereal Time (GST).

USNO vs. STND vs. TEST. We will refer to the operational Intensives scheduled by USNO as USNO Intensives, or USNO for short. These use a restricted list of sources. In our study we scheduled two different kinds of Intensives. The STND (standard) Intensives used the restricted USNO source list. The TEST Intensives used an enlarged list containing all sources that are mutually visible at Kokee and Wettzell.

Greenwich Sidereal Time. Because the sessions in our study are single baseline and of short duration, they only sample a small slice of the sky. The slice changes depending on the date and time of the Intensive. Intensives scheduled on the same date, but at different times, can sample very different slices of the sky. Similarly, Intensives scheduled on different dates can observe the same slice of the sky. To be able to compare sessions, we make use of the fact that Intensives that start at the same Greenwich Sidereal Time (GST) sample the same slice of the sky, regardless of the date or UT time of the session.

3. Designing the Sessions

We divided the R&D network into two parts: the single baseline Kokee—Wettzell network and a network consisting of approximately five remaining stations. We scheduled each network independently. The primary purpose of the larger network was to serve as an independent check on UT1, and we scheduled it similarly to the R1s and R4s, using the standard R1 observing sequence.

Table 1. Scheduled Intensive Study R&D Sessions.

Start time of R&D Sessions

	RD0907		RD0908		RD0909		RD0910	
Date	2009Jul08		2009Sep23		2009Oct06		2009Dec16	
	UT	GST	UT	GST	UT	GST	UT	GST
Start	18:00	13:07	18:00	18:10	17:30	18:32	18:00	23:42

Alternating Intensives in GST order.

STND	5:00	0:09	0:00	0:11	23:10	0:12	USNO	
TEST	6:00	1:09	1:00	1:11	0:10	1:13	**19:30**	**1:12**
STND	7:00	2:09	2:00	2:12	1:10	2:13	20:30	2:12
TEST	8:00	3:09	3:00	3:12	2:10	3:13	21:30	3:12
STND	9:00	4:09	4:00	4:12	3:10	4:13	22:30	4:12
TEST	10:00	5:09	5:00	5:12	4:10	5:13	23:30	5:12
STND	11:00	6:10	6:00	6:12	5:10	6:13	0:30	6:13
TEST	12:00	7:10	7:00	7:12	6:10	7:14	1:30	7:13
STND	13:00	8:10	8:00	8:13	7:10	8:14	2:30	8:13
TEST	14:00	9:10	9:00	9:13	8:10	9:14	3:30	9:13
STND	15:00	10:10	10:00	10:13	9:10	10:14	4:30	10:13
TEST	16:00	11:10	11:00	11:13	10:10	11:14	5:30	11:13
STND	17:00	12:11	12:00	12:13	11:10	12:14	6:30	12:14
TEST	USNO		13:00	13:13	12:10	13:15	7:30	13:14
STND	Intensive		14:00	14:14	13:10	14:15	8:30	14:14
TEST	**20:00**	**15:07**	15:00	15:14	14:10	15:15	9:30	15:14
STND	21:00	16:07	16:00	16:14	15:10	16:15	10:30	16:14
TEST	22:00	17:07	17:00	17:14	16:10	17:15	11:30	17:14
STND	23:00	18:08	USNO		USNO		12:30	18:15
TEST	0:00	19:08	Intensive		Intensive		13:30	19:15
STND	1:00	20:08	**20:00**	**20:11**	**19:10**	**20:12**	14:30	20:15
TEST	2:00	21:08	21:00	21:11	20:10	21:12	15:30	21:15
STND	3:00	22:08	22:00	22:11	21:10	22:12	16:30	22:15
TEST	4:00	23:08	23:00	23:11	22:10	23:12	Intensive	

Session start times are indicated in **bold**.

"USNO Intensive" indicates periods when Kokee & Wettzell participated in USNO Intensives and were unavailable for the R&D sessions.

	USNO Intensives on R&D Days							
	I09189		I09266		I09279		I09350	
Start	18:30	13:37	18:30	18:40	17:30	18:32	18:00	23:42
End	19:30	14:37	19:30	19:40	18:30	19:32	19:00	00:42

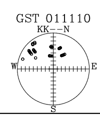
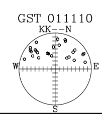
Because Kokee and Wettzell are used in the USNO Intensives, they were not available for the two-hour period immediately prior to, during, and after the USNO Intensives. In the first R&D the stations became available at 19:45 UT. Starting at 20:00 UT we scheduled a series of 22 alternating TEST and STND Intensives. We adjusted the start times of the Intensives in the remaining R&Ds so that we sampled the same slices of the sky; all of the STND Intensives start close to the even hours in GST, while all of the TEST Intensives start close to the odd hours.

Table 1 lists the four R&Ds scheduled for our study[1]. The top of the table displays the name and date of each R&D session. Each start time is specified in both UT and GST. Following this are the start times of the alternating Intensives in each session. Rows are organized to clearly indicate the correspondence in GST across the sessions. The first column indicates the scheduling strategy—STND or TEST, and the remaining columns give the start times in UT and GST. We indicate the first Intensive in each R&D session by **bold face**. The remaining Intensives are found by reading down to 23:xx GST, and then starting at the top.

4. Differences between Observing Strategies

The effect of the different source lists had a marked difference on the schedules generated. This is summarized in Table 2, which shows two typical schedules. The STND strategy has more observations because it uses a few strong sources. The TEST strategy uses more, but weaker, sources. Because of this it has fewer observations, but its sky coverage is better.

Table 2. Comparison of Intensive scheduling strategies.

	STND	TEST
Typical Sky Coverage		
Average number of observations	**28.3**	23.2
Average number of sources	10.6	**18.5**
Source Strength	**Stronger**	Weaker
Sky coverage	Narrower	**Wider**

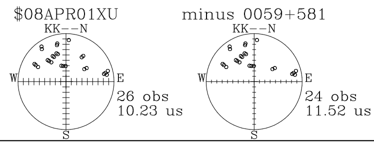
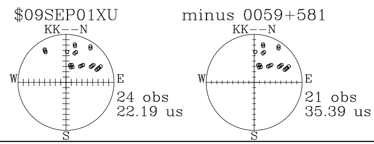
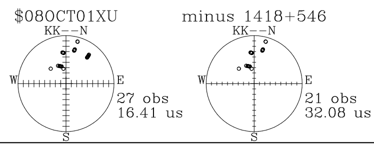
Bold indicates the strategy that is better for UT1 estimates.

5. Current Strategy and Source Dropouts

Better sky coverage is empirically linked with improved precision and accuracy of the UT1 estimates. The current USNO strategy uses only the strongest sources, but because strong sources are unevenly distributed, only a few are available at some times of the year, which can result in poor sky coverage. Furthermore, because the number of available sources is small, the USNO strategy tends to schedule sources many times in one session. The loss of a single source can lead to dramatic changes in sky coverage, which in turn has a large effect on the UT1 formal errors, as illustrated in Table 3 for three schedules. For each schedule we deleted a single source. The effect ranges from minimal (10% degradation in sigma) to doubling the formal error.

[1]RD0910 was not correlated in time for this study, so the analysis only includes RD0907 through RD0909.

Table 3. Effect of losing one source on UT1 formal errors.

Sky Coverage	When	Charts
Good	GST 07:12 April 1-5	
Intermediate	GST 17:11 Sep 1-5	
Bad	GST 19:12 Oct 1-4	

6. Robustness of the TEST and the USNO Schedules

Sessions are prone to lose observations. Ideally, we would like the estimated parameters to be insensitive to this loss. A session is robust if the parameters do not change very much with the loss of a single source. To compare the robustness of the techniques, we selected four USNO Intensives with varying levels of sky coverage ranging from good to bad, and we paired these with TEST Intensives. For each session we ran a set of solutions in which we suppressed a single source and estimated UT1. We did this for all sources in the session, and then computed the scatter of the estimates. These results are summarized in Table 4. The TEST schedules are much more robust because their sky coverage is better and because they use more sources. Hence the loss of a single source does not change the sky coverage as much as in the USNO Intensives.

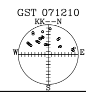
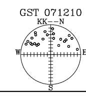
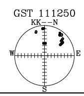
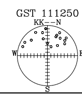
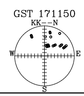
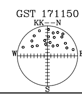
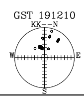
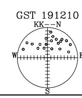
7. Comparison of the TEST and the USNO Schedules

We purposely designed our study so that the TEST sessions would sample the same slice of the sky as other TEST sessions, and the same for the STND sessions. This has the advantage that, for a particular GST, we have more sessions of a given kind. It has the disadvantage that it makes it difficult to directly compare the TEST and the STND sessions.

One way around this is to compare the TEST sessions with USNO sessions. The advantage of doing so is that you can ensure that you are sampling the same slice of the sky. The disadvantage is that the weather, which influences the noise, will be different, since these sessions are at different times of the year.

Our TEST sessions sample 12 slices of the sky. We looked at all USNO Intensives from 2007—2009 that started at the same GST as the TEST sessions. For each of the two Intensive sets, we calculated the average UT1 formal error σ and the average session fit. These are summarized in Table 5. The TEST strategy generally has lower UT1 formal errors. Examination of the exceptions indicates that the TEST strategy can introduce weaker sources that drive up a session's fit and

Table 4. RMS scatter in UT1 estimates after deletion of successive single sources.

Sky Coverage	GST	USNO	RMS	TEST	RMS
Good	07:12		5.3		4.4
Intermediate	11:12		12.2		7.4
Intermediate	17:11		13.2		2.9
Bad	19:12		21.6		4.4
Average RMS			13.1		4.8

in turn its UT1 formal error. If the USNO schedule has especially good sky coverage, the TEST schedule may suffer in comparison. It may be possible to compensate for this by excluding weaker sources in the TEST schedules.

Table 5. Comparison of USNO and TEST UT1 formal errors (σ) and session fits[2].

	USNO		TEST	
	$\sigma(\mu s)$	Fit (ps)	$\sigma(\mu s)$	Fit (ps)
Average	14.5	47.5	10.9	54.3
StdDev	4.8	9.7	3.3	13.9

8. Conclusions and Future Work

The results of the TEST scheduling strategy are very encouraging. The TEST strategy yields schedules which are more robust than the USNO Intensives, and on average the UT1 formal errors are 30% better for the TEST sessions. In cases where the TEST formal errors are worse, changing a parameter of the TEST algorithm might compensate. Much of the improvement in the TEST schedules compared to the USNO schedules is due to having more sources and better sky coverage.

We requested, and were granted, the use of five more R&D sessions in 2010. In these new sessions the TEST and STND series will trade the slices of the sky they sampled in RD0907 through RD0910. This will allow us to directly compare the TEST and STND strategies.

The authors would like to thank David Gordon for providing helpful advice about using Greenwich Sidereal Time to compare the Intensive sessions.

[2]Due to space limitations, only a partial version of this table is presented here. Please refer to ftp://ivscc.gsfc.nasa.gov/pub/general-meeting/2010/presentations/GM2010_S3P07_baver.pdf for the full table.