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# Analysis of the VLBI Intensive Sessions

*Karen Baver [1], Daniel MacMillan [2], Leonid Petrov [2], David Gordon [1]*

[1] *Raytheon ITSS/NASA Goddard Space Flight Center*
[2] *NVI, Inc./NASA Goddard Space Flight Center*
*Contact author: Karen Baver, e-mail:* kdb@leo.gsfc.nasa.gov

**Abstract**

Intensive sessions were designed to determine UT1 with minimum latency. Therefore UT1 from these sessions is the highest priority service which IVS provides to a wide community of users. We have analyzed the IVS-INT1 (KOKEE-WETTZELL) Intensives and the IVS-INT2 (TSUKUB32-WETTZELL) Intensives. Here we present results of our analysis of the performance of these two Intensive series, and we compare them to other UT1 series. We investigate the precision of the Intensive UT1 series. We also examine the dependence of session performance on the selection of observed sources, and we discuss improvement of the observing schedules.

## 1. Introduction

Intensive sessions were designed to determine UT1 with minimum latency. Therefore these sessions provide a high priority service to a wide community of users. UT1 from the Intensive sessions was of recent critical importance to the Mars spacecraft navigation team at JPL. IVS currently provides two series, the IVS-INT1 or NEOS series, which used the NRAO20-WETTZELL baseline until July 2000 but has subsequently used the KOKEE-WETTZELL baseline, and the IVS-INT2 series, which uses the TSUKUB32-WETTZELL baseline. The IVS-INT1 series provides most of the data–approximately four sessions weekly (currently Monday, Tuesday, Wednesday, and Friday) since January 1997; earlier sessions exist but are not currently included in the GSFC VLBI eopi product. The IVS-INT2 series began in July 2002, with two to six sessions per month except for a hiatus from mid-December of 2002 through mid-April of 2003. This series plays an important role in supplementing the IVS-INT1 series, because it provides data on a day of the week not covered by the IVS-INT1 series (Saturday).

## 2. Performance of the IVS-INT1 and the IVS-INT2 Series

To compare the IVS-INT1 and the IVS-INT2 series, we ran a solution for each series, using SOLVE to estimate six parameters (UT1-TAI offset, one atmospheric offset per site, and a clock offset, rate and second order term). We restricted the IVS-INT1 solution to 275 sessions between July 2002 and December 2003 to match the time frame of the 48 available IVS-INT2 sessions. All IVS-INT1 sessions used KOKEE-WETTZELL during this time, except for four sessions in October 2003 in which WESTFORD replaced KOKEE due to operational problems at KOKEE.

Figure 1 shows differences of the IVS-INT1 UT1 (left column) values and the IVS-INT2 (right column) values to UT1 from the GSFC 2004a solution for 24-hour sessions (top row) and the IERS C04 series (bottom row). Note that here time differences between each Intensive session and the nearest 24-hour session were up to 12 hours for IVS-INT1 and up to 28 hours for IVS-INT2, which accounts for the larger IVS-INT2 WRMS difference.

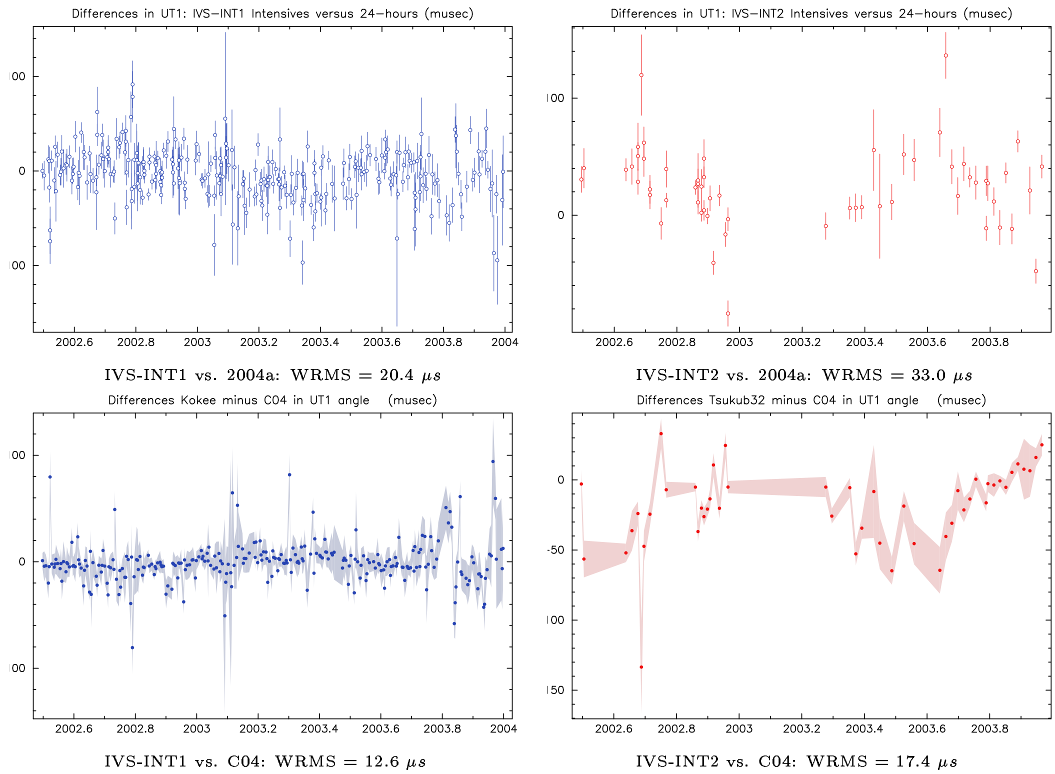


Figure 1. Differences between UT1 from the Intensives (IVS-INT1: left, IVS-INT2: right) and from the 24-hour series (GSFC 2004a quarterly solution) (top row) and from the C04 series (bottom row).

Comparisons of IVS-INT1 and IVS-INT2 in Figure 2 and Table 1 show that the formal errors and the session fits (WRMS residual delays) are better for IVS-INT2. This conclusion may change somewhat with more IVS-INT2 sessions, but at this point, the comparison shows that IVS-INT2 is performing at least as well as IVS-INT1.

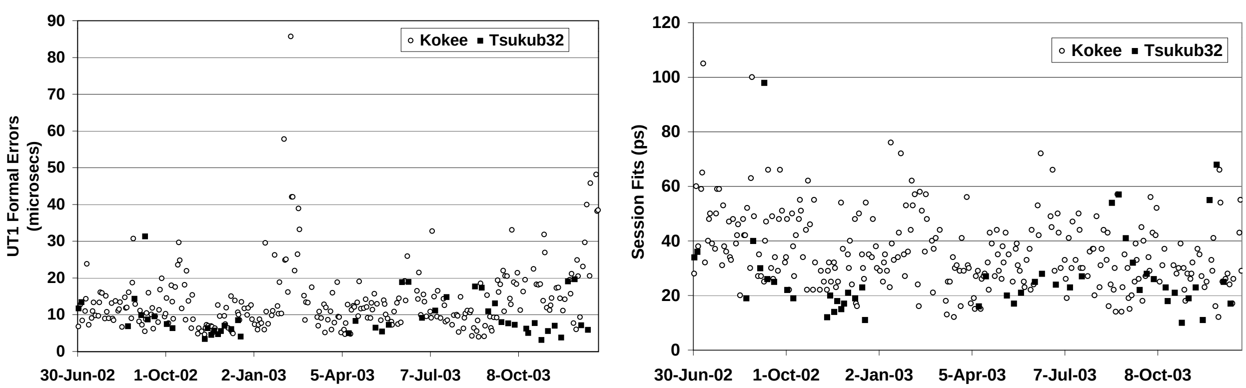


Figure 2. IVS-INT1 and IVS-INT2 UT1 formal errors (left) and session fits.

Table 1. Comparison of IVS-INT1 and IVS-INT2

| UT1 Formal Error ($\mu s$) | | |
|---|---|---|
| | IVS-INT1 | IVS-INT2 |
| average | 13.94 | 9.45 |
| st. dev. | 9.19 | 5.60 |

| Session Fit (ps) | | |
|---|---|---|
| | IVS-INT1 | IVS-INT2 |
| average | 36.11 | 27.02 |
| st. dev. | 13.86 | 16.10 |

## 3. Intensive Session Precision

We have computed the differences between UT1 from each Intensive and the UT1 from the 24-hour session that is closest in time to this Intensive. The UT1 from the 24-hour session was linearly extrapolated to the Intensive session time using the UT1 rate for the 24-hour session. For each Intensive series, the observing time differences fall within several distinct groups, where the time differences are all within 2-3 hours of each other in each group. The WRMS of the differences for each group are shown in Figure 3 as a function of the corresponding time differences. This WRMS is a measure of the precision of the Intensives. The WRMS grows due to extrapolation error. An estimate of the linear extrapolation error was computed from a spline (degree 3) interpolation of a standard GSFC daily UT1 Kalman-filtered series that was generated from 24-hour session estimates. The extrapolation error roughly follows the curve $20\mu s/day^{3/2}T^{3/2}$. The open points were obtained by subtracting this extrapolation error (in quadrature) from the observed WRMS. The observed precision is then 18-22 $\mu s$ for both series for comparisons with T $<$ 24 hours.

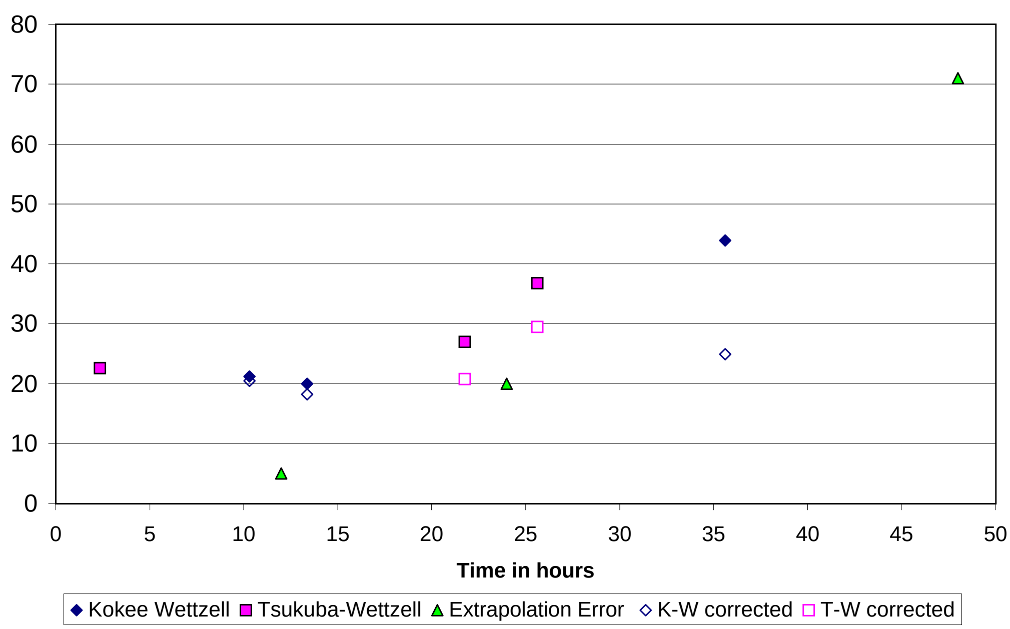


Figure 3. Original and corrected UT1 WRMS Differences in $\mu s$ between Intensives and 24-hour sessions.

## 4. Formal Precision of the IVS-INT1 Series from 1999 through 2003

Figure 4 shows UT1 formal error measurements for the primary (IVS-INT1) series over five years (January 1999 through December 2003) except for seven outliers over 60 $\mu s$ excluded to better show the scale. The time period is divided into three periods delimited by the vertical lines. The first period (January 1999 through June 2000) used the NRAO20-WETTZELL baseline. The middle and last periods (July 2000 through December 2003) both replaced NRAO20 with KOKEE (except for four October 2003 sessions in which WESTFORD replaced KOKEE due to problems at KOKEE), but different observing modes were used during these periods. The middle period (July 2000 through May 2001) used the same mode as the first period, but during the last period (June 2001 through December 2003), the data acquisition rate was doubled to 8 Mbps, and the observing time was reduced from ∼1.5 hours to ∼1 hour. Average session fits and average UT1 formal errors for the three periods are given in Table 2. The session fits were significantly better for the shorter NRAO20-WETTZELL baseline sessions. The third period UT1 formal error shows noticeable improvement over the other periods. More investigation is required to understand the effects of the changes in baseline and observing mode.

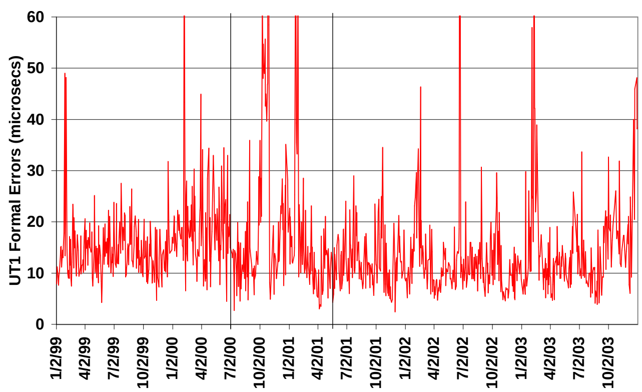


Figure 4. IVS-INT1 formal precision, 1999-2003.

Table 2. IVS-INT1 statistics, 1999-2003.

| | NRAO20-WETTZELL | KOKEE-WETTZELL | |
|---|---|---|---|
| | 4 Mbps/1.5 hr (1/99-6/00) | 4 Mbps/1.5 hr (7/00-5/01) | 8 Mbps/1 hr (6/01-12/03) |
| Avg. UT1 formal error ($\mu s$) | 16.039 | 18.076 | 13.541 |
| Avg. Session fit (ps) | 28.215 | 36.612 | 38.690 |
| Number of sessions | 326 | 170 | 484 |

## 5. Source Selection

Source distribution is important to achieving a low UT1 formal error. Figure 5 shows the distributions of sources for $00OCT16XU and $00NOV20XU, two IVS-INT1 sessions with similar session fits (31 and 32 ps, respectively) and equal numbers of observations (15), but with very different UT1 formal errors (48.97 and 12.66 $\mu s$, respectively). The session with the smaller formal error has lower declination sources and wider sky coverage. Examination of source distribution plots for other sessions empirically shows a general connection between wider sky coverage and smaller formal errors. It is generally considered to be important to observe sources closer to the equator. However, there are sessions with small UT1 formal errors that have wide sky coverage but no observations of sources below 30 degrees in declination. More work is required to completely understand this.

Since the distribution of lower declination sources in the geodetic observing catalog is not optimal for the Intensives, we tested the suitability of potential sources by scheduling them in IVS-R4 and IVS-R1 sessions to determine their current flux densities. These sources range in declination from 11.5 to 25 degrees and were mostly drawn from the VCS1 and VCS2 VLBA calibrator survey sessions. Figure 6 shows the standard GSFC VLBI geodetic catalog sources and the candidate Intensive sources.

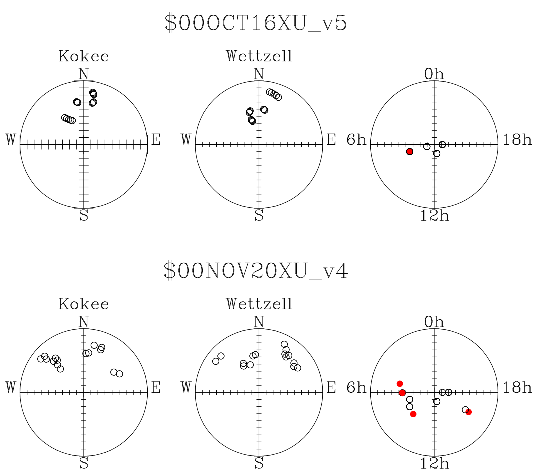


Figure 5. Effects of source distribution which resulted in bad (top) and good (bottom) UT1 formal errors (48.97 vs. 12.66 $\mu s$, respectively). The filled circles on the RA/DEC plots represent observations that were under 15 degrees of elevation at one site.

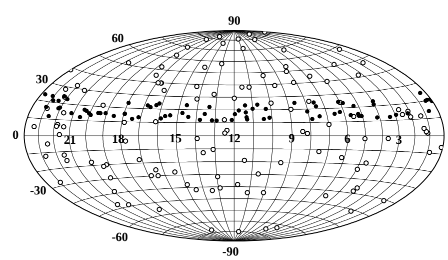


Figure 6. Existing GSFC VLBI sources (open circles) and candidate Intensive sources (solid circles).