Performance of the Operational IVS-R1 and IVS-R4 Sessions

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Abstract This paper focuses on the performance of the operational IVS-R1 and IVS-R4 sessions from 2002 through 2017. The formal uncertainties of the IVS-R1 and IVS-R4 EOPs improved over the period of 2002 through 2017. We consider how much this improvement can be attributed to the increased size of the networks, changes in the data rate, the number of observed sources, and/or the scheduling parameters.

Keywords IVS-R1, IVS-R4, EOP

1 Introduction

In this paper we focus on the EOP (Earth Orientation Parameter) performance of the operational IVS-R1 and IVS-R4 sessions from 2002 through 2017. The IVS-R1 and IVS-R4 sessions began in January 2002 with a network of five to six stations and increased over time to a network size of 11 to 13 stations in 2017. There is significant variation in observed EOP precision over different time periods; for instance, the precision in the time period around the continuous observing campaign CONT14 was close to the precision of CONT14. We investigate the possible factors that could produce better or worse precision for the IVS-R1 and IVS-R4 networks from 2002 through 2017. Some factors that could help explain the variability in observed EOP precision are network station variation, media, data loss, and recording rate. All of these factors are examined in our analysis of the performance of the IVS-R1 and IVS-R4 series from 2002 through 2017.

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2 EOP Uncertainties of the IVS-R1 and IVS-R4 Sessions

The EOP uncertainty goal of the IVS program is 3.5 µs for UT1 and 100 µas for pole position. As shown in Figure 1, the formal uncertainties meet this goal and have improved over time. The moving average (one year) trend line for IVS-R1 pole position uncertainties decreases from 60 µas in early 2002 to 40 µas in late 2017. The moving average (one year) for IVS-R1 UT1 becomes more stable, but there is no significant linear trend. There is a more significant improvement over time in all EOP components for the IVS-R4 sessions. The moving average (one year) trend line for IVS-R4 X-pole position improves from 90 µas in early 2002 to 40 µas in late 2017 and from 70 µas in early 2002 to 40 µas in late 2017 for Y-pole. The UT1 uncertainties decrease from 3 µs to 2.5 µs over the 16-year period.

3 2014 & 2017 IVS-R1 & IVS-R4 & CONT Sessions

We wanted to know if the IVS-R1 and IVS-R4 sessions, scheduled before and after the CONT campaigns, had better formal uncertainties, since it is possible that the increase in station checkout before CONT campaigns could contribute to better performance for all sessions involving CONT stations. We see in Figure 2 that this is true during 2014 for the IVS-R1 sessions scheduled before and after CONT14. However, this did not occur during 2014 for the IVS-R4 sessions or any other CONT campaign for the IVS-R1 or IVS-R4 sessions. This appears to be an

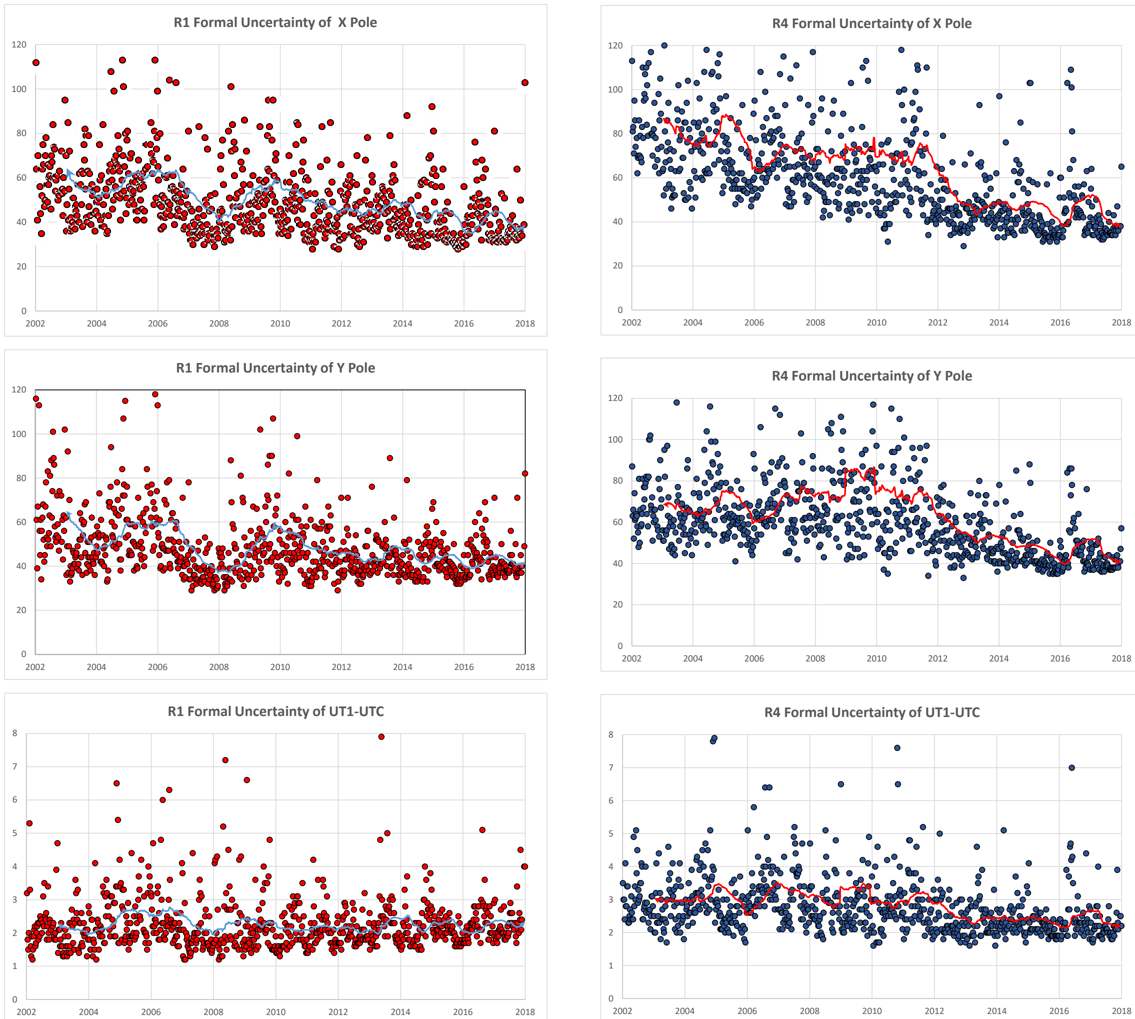

Fig. 1 IVS-R1 and IVS-R4 formal uncertainty of X-pole (µas), Y-pole(µas), and UT1 (µs) for the period of 2002 through 2017.

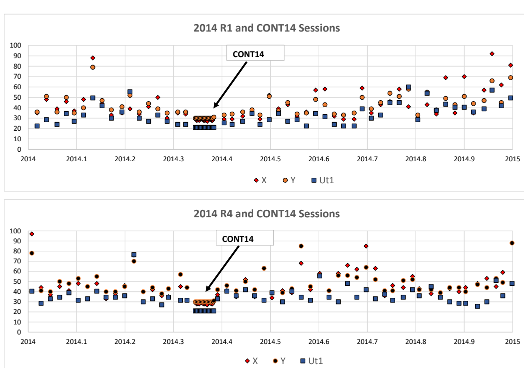

Fig. 2 2014 IVS-R1, IVS-R4, and CONT14 X-pole, Y-pole, and UT1 formal uncertainties (µas).

anomaly since it occurred only for CONT14 and for only one type of session.

4 EOP Uncertainties of the IVS-R1 and IVS-R4 Sessions with No Velocities Estimated

The standard VLBI solutions assume that you are doing a global estimate of station positions and velocities, and are estimating EOP on an arc-by-arc basis. Because of this, the uncertainties in the reference frame propagate into the EOP uncertainties. The reference frame has the least uncertainty in the middle of the data

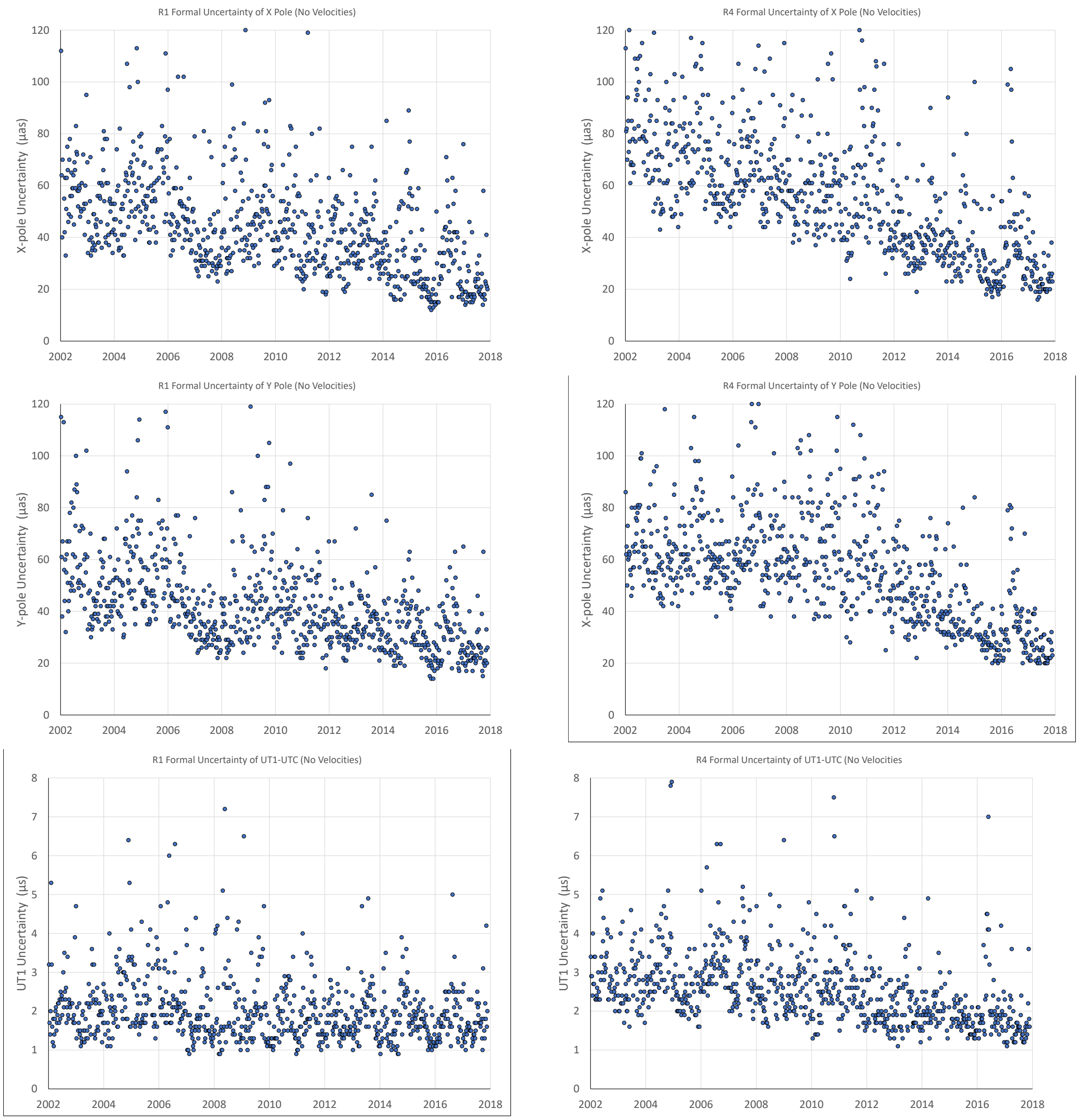

Fig. 3 IVS-R1 and IVS-R4 formal uncertainty of X-pole, Y-pole, and UT1 for the period of 2002 through 2017 – no velocities.

span, and increases towards the end. Because of this, even if the network and observing schedules remained the same, the EOP uncertainties would be larger towards the end of the observing span. An alternative way of studying the EOP uncertainties is to turn off reference frame estimation by turning off velocity estimation. The resulting EOPs are only influenced by the observing schedule and allow a truer comparison of EOP uncertainty at different epochs.

Figure 3 shows that the EOP formal uncertainties without velocity estimation improved from 2002 through 2017. The X-pole and Y-pole uncertainties for the IVS-R1 sessions improved by a factor of two and UT1 by a factor of about 1.5. There is a larger change with the IVS-R4 sessions where X-pole improves by a factor of three and Y-pole improves by a factor of two. UT1 improves by a factor of two.

5 Number of Observations Per Session

Figure 4 shows that the network size for both the IVS-R1 and IVS-R4 sessions increased. Depending on the network, the increased network also caused the number of observations to increase. The IVS-R1 first increased in network size in 2006, up to eight stations. There was a more significant increase in 2011 to ten stations and then 10+ stations in 2015. The IVS-R4 sessions first increased in network size in 2003, then 2011 to ten stations and later in 2014 to 11+ stations.

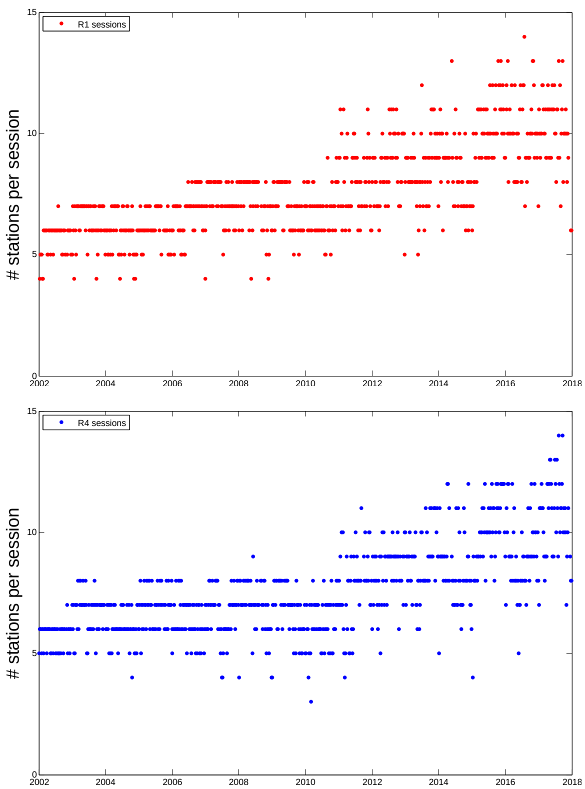

Fig. 4 IVS-R1 (top) and IVS-R4 (bottom) stations per session from 2002 to 2017.

Figure 5 displays the general increase in the number of obserations per session for the IVS-R1 and IVS-R4 sessions since 2002. There is an increase in session observations for the IVS-R1s that begin in August of 2006 and levels off until 2010. The August 2006 increase is consistent with the replacement of tapes with disks. Observations increased because tapes had required extra idle time due to tape turn-around and tape change. There is another increase starting in 2010 when AuScope stations were added to the IVS-R1 sessions. The number of observations continued to increase as Sejong was added to the network in the fall of 2014. Yebes-13.5m and Wettzell-North were tagged along and then added as regular stations in early and mid 2016, respectively. The increase starting at the end of 2015 can be attributed to an increase in the bit rate to 512 Mbps for the even IVS-R1 sessions.

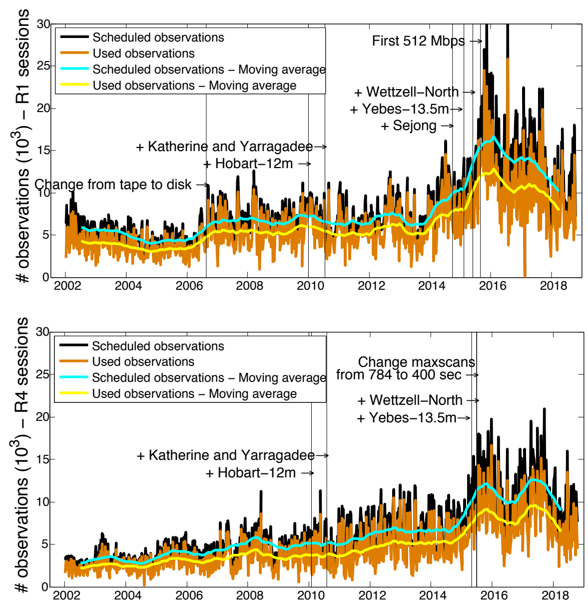

Fig. 5 Scheduled vs. good observations per IVS-R1 (top) and IVS-R4 (bottom) session (2002 through 2017).

The number of IVS-R4 observations increased steadily over time and the biggest increase came around mid 2014 to 2015 (Figure 5). The increase is primarily due to decreasing the maximum scan length from 784 to 400 seconds and the addition of Wettzell-North and Yebes-13.5m. We still need to investigate the reason for the short decrease in observations during 2016.

Figure 5 shows that, although the number of observations increased over the years for both the IVS-R1 and IVS-R4 sessions, the number of good observations decreased in 2016. The decrease in good IVS-R1 observations is especially large since the beginning of 2016, which needs to be studied to determine if the number of good observations can be increased. The number of successful IVS-R1 and IVS-R4 observations is on average about 80% of the observations scheduled from 2002 through 2017. We need to investigate how to improve this success percentage.

6 Conclusions

The EOP formal uncertainties improved for both the IVS-R1 and IVS-R4 sessions since 2002. There are many interesting issues that still need to be studied regarding these data sets. Simulations are used to design future experiments and are based on scheduled data; it is possible that simulation procedures should be improved. The observation success rate for both IVS-R1s and IVS-R4s is about 80%. The main conclusion is that we need to investigate how to improve the success rate. Clearly the formal uncertainties of estimated EOP will be improved with more successful observations resulting from reducing the gap between scheduled and used observations. We also intend to further study the sessions where the performance of the IVS-R1 and IVS-R4 sessions were best, specifically the IVS-R1 sessions before and after CONT14.