Performance of the Operational R1 and R4 Sessions

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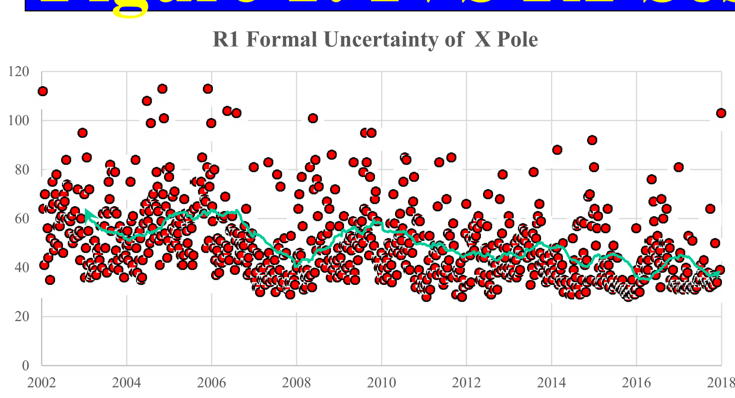
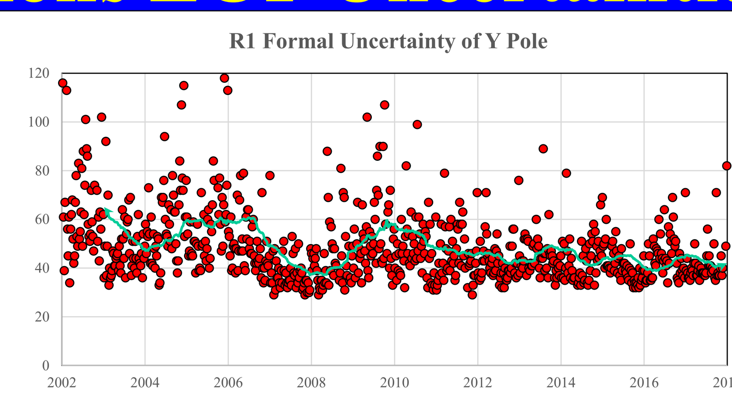
INTRODUCTION

This presentation focuses on the performance of the operational IVS-R1 and IVS-R4 sessions from 2002 through 2017. The formal uncertainties of the R1 and R4 EOPs improved over the period of 2002 through 2017. What contributed to the improvements: Number of stations; Improved frequency sequence; Increased data rates; SNRs; SEFDs?

Figure 1: IVS R1 Sessions EOP Uncertainties





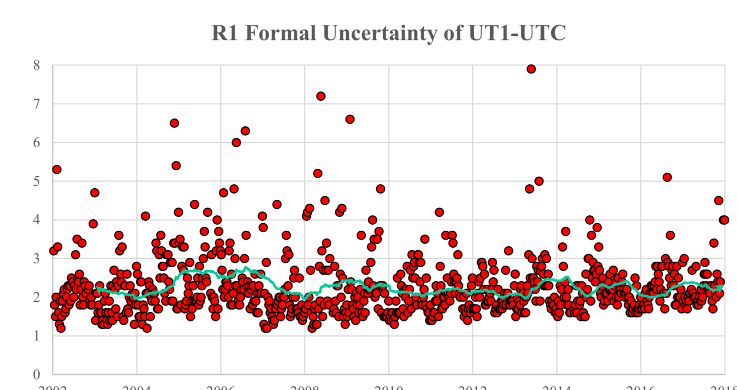
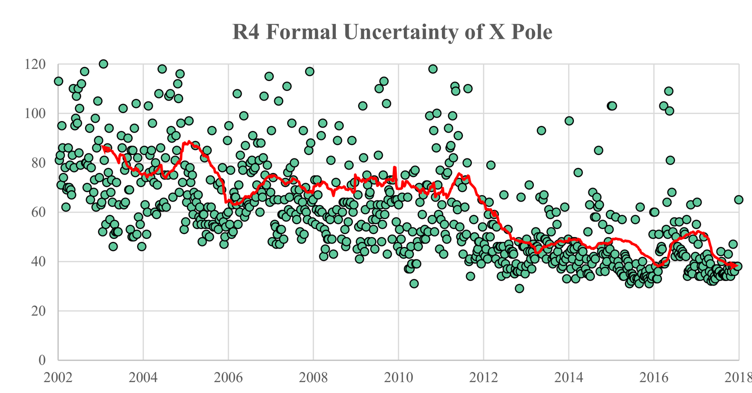
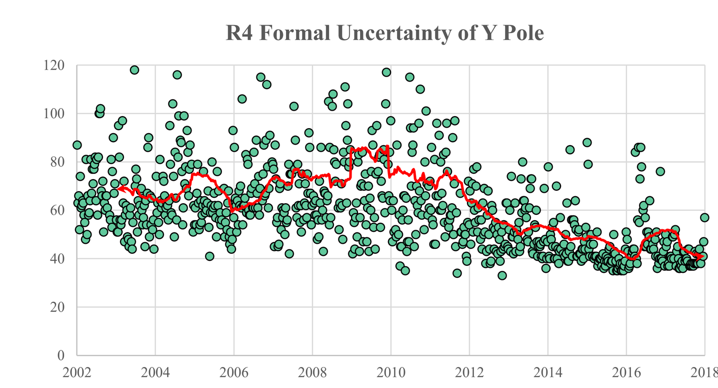
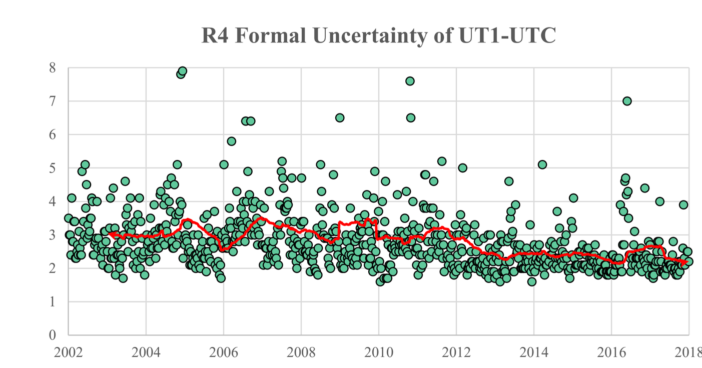


Figure 2: IVS-R4 Sessions EOP Uncertainties



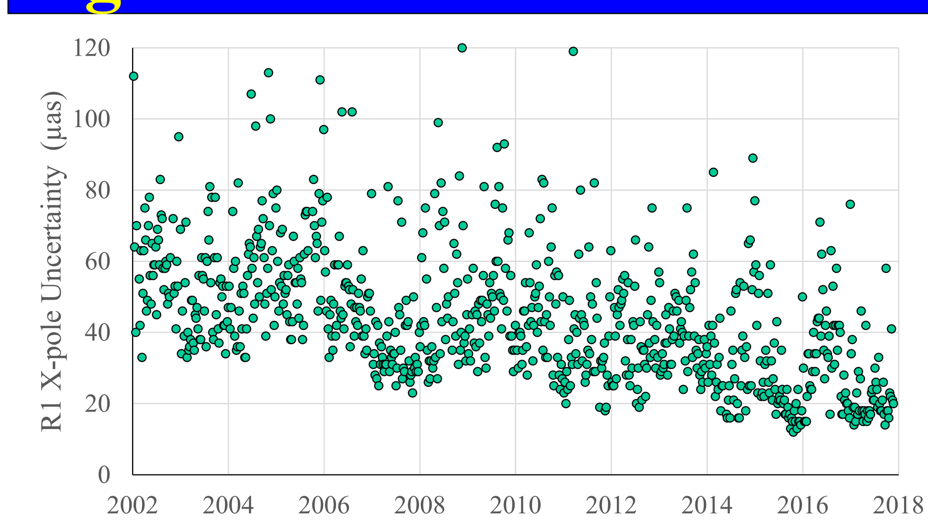


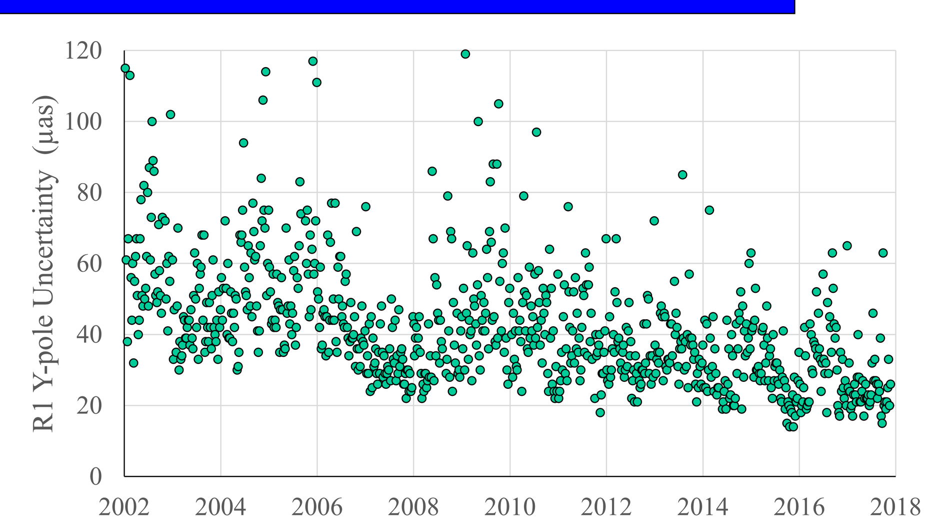


The EOP goal of the IVS program is 3.5 µs for UT1 and 100 µas for pole position. As shown in **Figure 1**, the formal uncertainties have improved over time for most of the components. The moving average (1 year) trend line for R1 pole position goes from 60 µas in early 2002 to 40 µas in late 2017. Whereas there is no change in the moving average (1 year) for R1 UT1. There is a more significant improvement over time in all formal uncertainty components for the R4 session **(Figure 2)**. The moving average (1 year) trend line for R4 pole position goes from 90 µas in early 2002 to 40 µas in late 2017 for X-pole and from 70 µas in early 2002 to 40 µas in late 2017 for Y-pole. The UT1 decreases slightly from 3 µs to 2.5 µs over the 16-year period.

Figures 3 and **4** show that the obtained EOP formal uncertainties without velocity estimation improved from 2002 through 2017. The X-pole and Y-pole uncertainties for the R1 improved by a factor of 2 and the UT1 goes from slightly above 1 µs to slightly below 1 µs. There is a larger change with the R4 sessions where X-pole improves by a factor of 3 and Y-pole improves by a factor of 2. UT1 improves by a factor of 2.

Figure 3: IVS R1 EOP Uncertainties - No Velocities





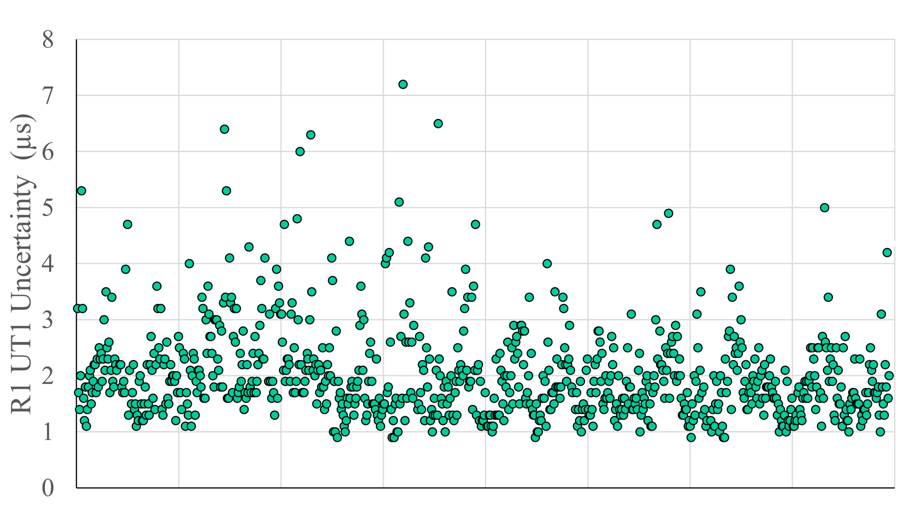
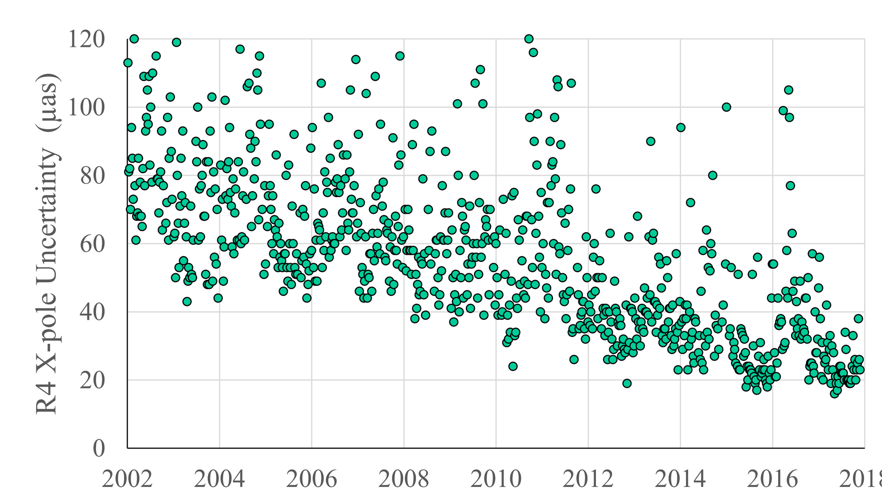
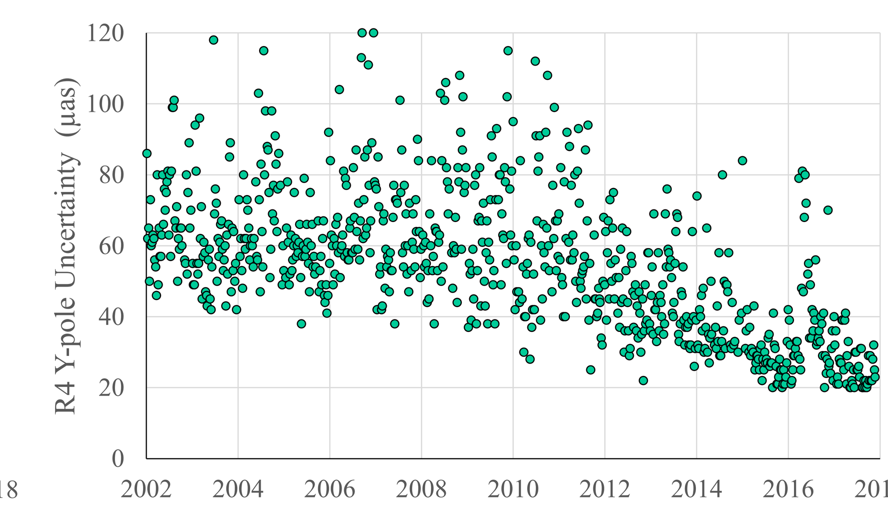
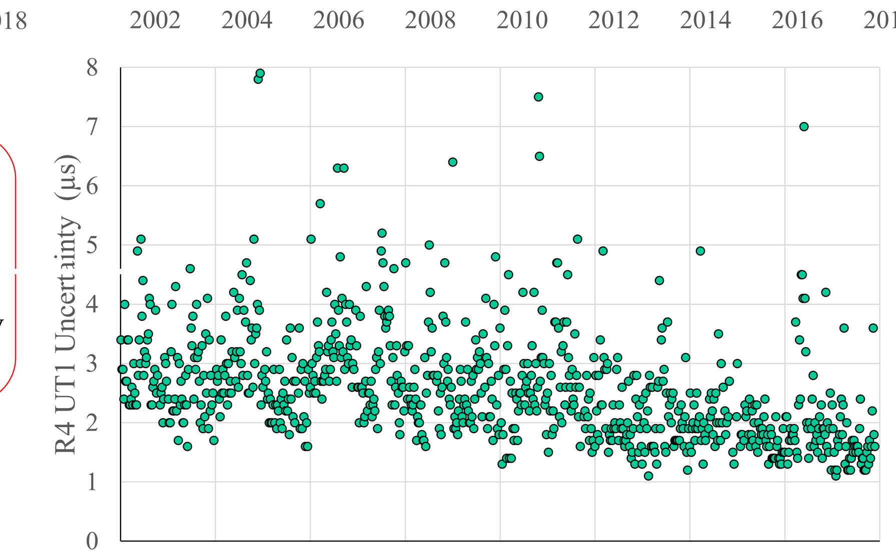


Figure 4: IVS R4 EOP Uncertainties - No Velocities







The standard VLBI solutions assume that you are doing a global estimate of station position and velocity, 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 span, and increases towards the end. Because of this even if the network and observing schedules remained the same, the EOP estimates would be larger towards the end of the observing span. An alternative way of studying the EOP estimates 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 5: Number of Observations Per Session

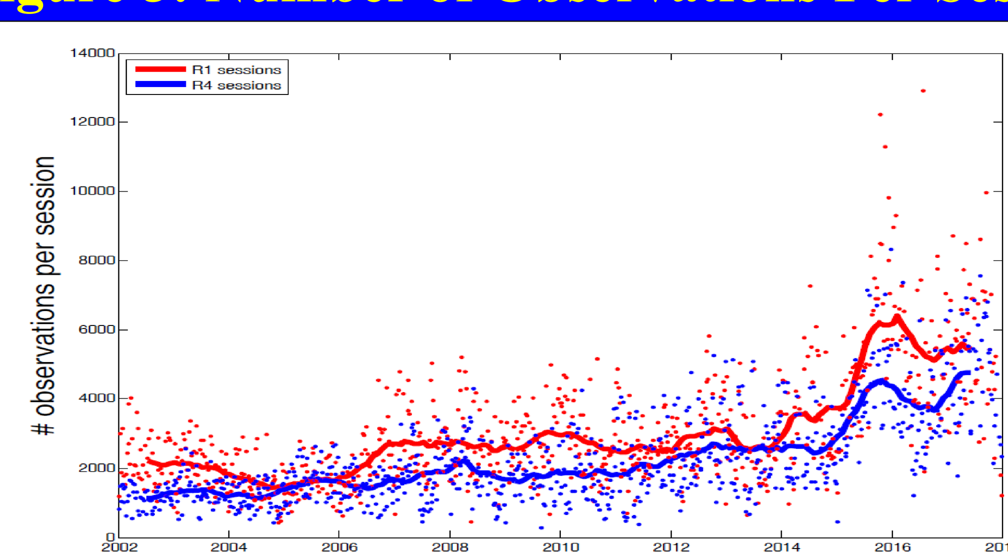
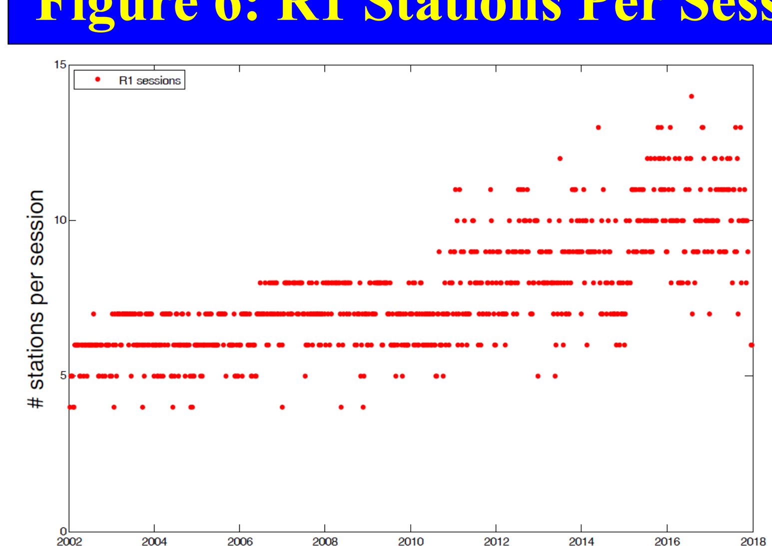
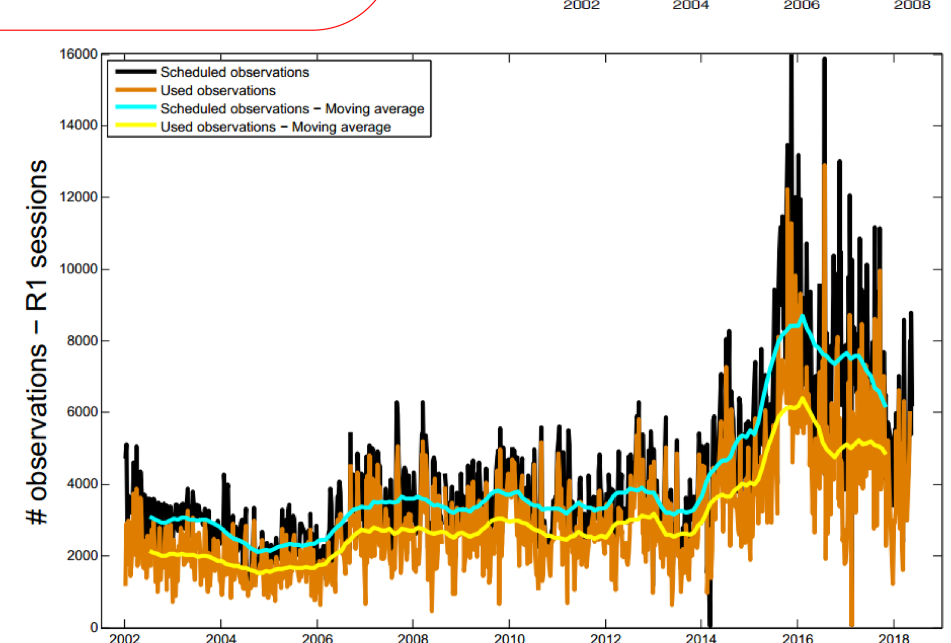


Figure 5. The increase in observations for R1s appears to begin in 2006, and level off in 2007. (This is consistent with the replacement of disks for tapes.) The observations increased because tapes require extra idle time due to tape turn-around and tape change. The increase continues in 2008 due to decreasing the maximum scan length from 600 to 200 seconds. The increase in 2016 can be attributed to increase in the bit rate to 512 Mbps for the even R1 sessions. It was at first thought that the increase in observations up to 2008 could be attributed to the increase in the network size but the R1 network ranged from 4 to 8 stations through 2009 **(Figure 6).** The chart to the lower right shows that the gap between scheduled and used observations is increasing. This should be investigated further to determine why this gap is increasing and what could be done to reduce it.

Figure 5. The number of R4 observations increased steadily over time and the biggest increase came around mid 2015 to 2016. The increase is primarily due to decreasing the maximum scan length from 784 to 400 seconds. We still need to investigate the reason for the short decrease in observations during 2017. It was thought that this increase in observations was attributed to only the increase in the network size since 2010 **(Figure 7).** The chart to the lower left shows the gap between scheduled and used observations is increasing. This needs to be investigated further as we discussed for the R1s.

Figure 6: R1 Stations Per Session





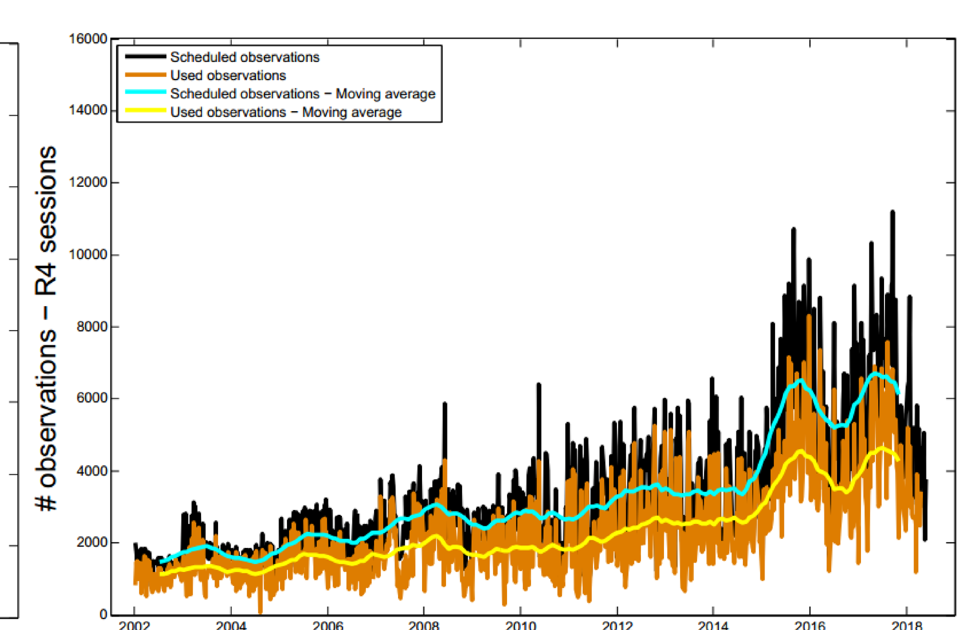
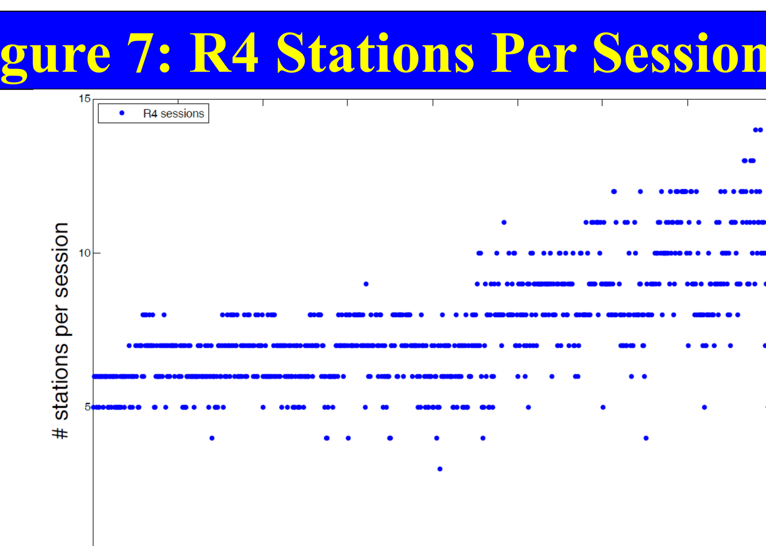
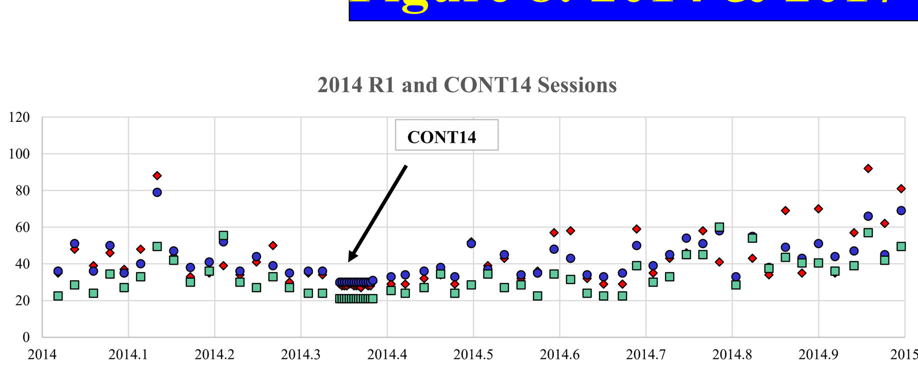


Figure 7: R4 Stations Per Session



We wanted to know if the R1 and 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 that it is true during 2014 for the R1 sessions scheduled before and after CONT14. However, this did not occur during 2014 for the R4 sessions or any other CONT campaign for the R1 or R4 sessions. This appears to be an anomaly since it occurred only for CONT14 and for only one type of session.

Figure 8: 2014 & 2017 IVS-R1 & CONT Sessions



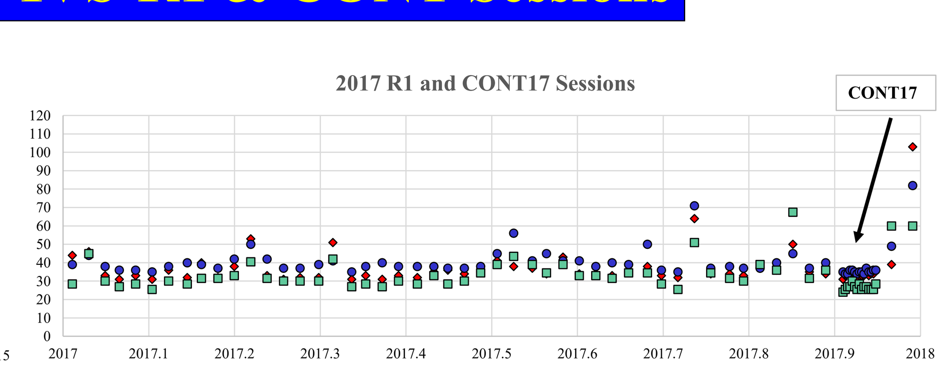
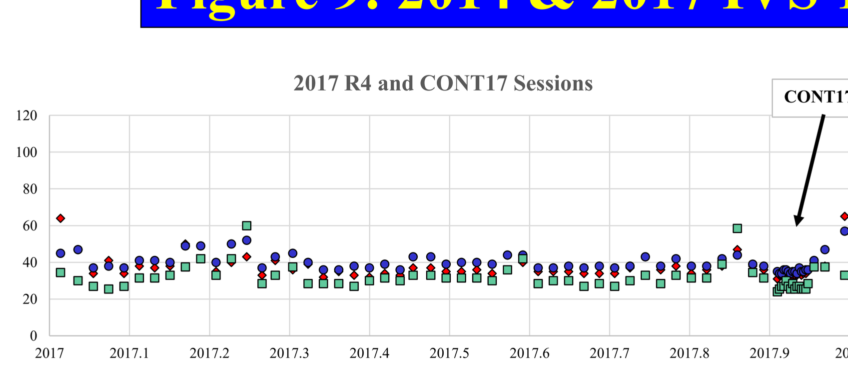
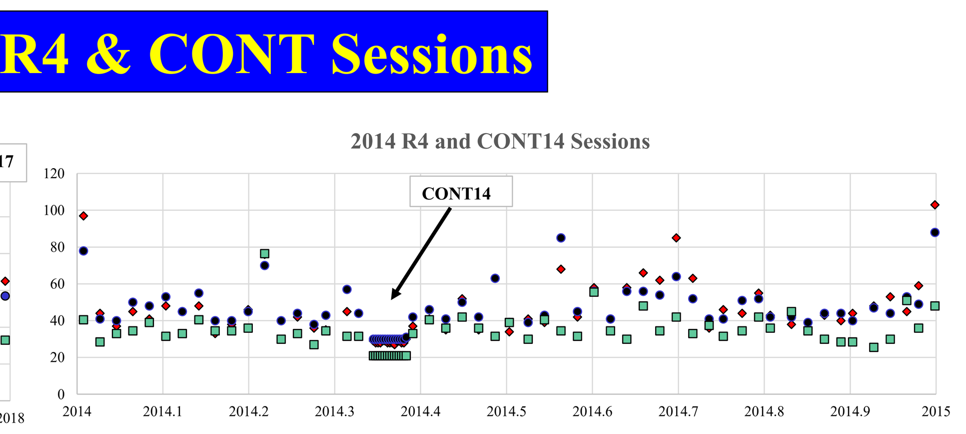


Figure 9: 2014 & 2017 IVS-R4 & CONT Sessions





The EOP formal uncertainties improved for both the R1 and R4 sessions since 2002. There are many interesting issues that still need to be studied regarding these data sets. Simulations are being used to design future experiments and are based on scheduled data; it is possible that simulation procedures should be improved. We need to resolve the reasons for the large difference between scheduled and used observations. 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 R1 and R4s were best and specifically the R1 sessions before and after CONT14.

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