KALMAN FILTER ANALYSIS OF SEARCH 92 VLBI DATA

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ABSTRACT: An analysis of the very long baseline interferometer data collected during the Epoch 1992 campaign is presented. A standard analysis is discussed in which tidally coherent, diurnal and semidiurnal polar motion and UT1-UTC variations are applied prior to Kalman filtering the VLBI data for stochastic estimates of 3-hourly binned estimated of pole position and UT1-UTC. Variants of this analysis are discussed to show the sensitivity of the results choice of process noise parameters and the apriori application of the tidally coherent models. Here the residuals between a smoothed VLBI polar motion and UT1 apriori series are shown. For pole position, this apriori series is very similar to IERS Bulletin B. For UT1, the use of the VLBI series reduces by half the size of the UT1 residuals compared to IERS Bulletin B.

1. Introduction

We present here the analysis of the SEARCH 92 VLBI data set using two different analysis techniques: (1) estimation of sub-daily variations in polar motion and UT1 using a batched Kalman filter technique; and (2) direct estimation of the cosine and sine components of diurnal (frequency 1-cycle-per-sidereal day) and semidiurnal (2-cycles-per-sidereal day) signals in polar motion and UT1. The experiments analyzed here are listed in Table 1 along with the station participating in each experiment.

2. Data Analysis

The VLBI data were analyzed using the techniques discussed in Herring and Dong [1994]. The coordinates of the radio telescopes were constrained at the values determined from the analysis of VLBI data obtained between 1990 and 1993, and apriori constraint was taken to be the standard deviations obtained from the coordinate solution. The radio source positions were held fixed at the values obtained from 1990-1993 analysis. The MTT hydrostatic and wet functions used in the analysis [Herring, 1992] and the process noise used to stochastically model the wet delay variations was obtained using the algorithm discussed in Herring et al. [1990]. The ZMOA-1990-2 nutation series given in Herring [1991] was used as the apriori nutation series. Daily estimates of correction to this series were made in all analyses. The hydrogen masers were model with Allan standards of 10^{-14} at sampling intervals of 30 minutes as discussed in Herring et al. [1990].

TABLE 1: VLBI experiments analyzed

Start date	Description	Sites (first four characters)					
92/07/26	EUR9-HOFN-4	HOFN	WEST	GILC	WETT	ONSA	
92/07/27	IRISA-751	HOFN	WEST	GILC	WETT	ONSA	
92/07/28	Navex-G3	SANT	NRAO	KASH	HART	MATE	
92/07/28	RD-E-92A	WEST	FD-V	LA-V	GILC	KAUA	WETT
92/07/29	Navex-G4	SANT	ALGO	NRAO	KASH	HART	MATE
92/07/29	RDE-92B	WEST	FD-V	LA-V	GILC	KAUA	WETT
92/07/30	Navnet 187	RICH	MOJA	GILC	KAUA		
92/07/31	RDE-92C	WEST	FD-V	LA-V	GILC	KAUA	WETT
92/08/02	RDE-92D	WEST	LA-V	GILC	KAUA	WETT	
92/08/03	IRISA-752	WEST	ALGO	RICH	MOJA	WETT	
92/08/04	Navex-G5	SANT	NRAO	KASH	HART	MATE	
92/08/04	RDE-92E	WEST	FD-V	LA-V	GILC	KAUA	WETT
92/08/05	Navex-G6	SANT	ALGO	NRAO	KASH	HART	MATE
92/08/05	RDE-92	WEST	FD-V	LA-V	GILC	KAUA	WETT
92/08/06	Navnet-188	NRAO	RICH	MOJA	GILC	KAUA	
92/08/07	RDE-92G	WEST	FD-V	LA-V	GILC	KAUA	WETT
92/08/09	RDE-92H	WEST	FD-V	LA-V	GILC	KAUA	WETT
92/08/10	IRISA-753	WEST	ALGO	RICH	MOJA	WETT	
92/08/10	Navex-25	NRAO	GILC	KAUA	KASH	MATE	
92/08/11	XASIA-2	DSS45	HOBA	KASH	SESH	HART	WETT

The treatment of polar motion and UT1 subdaily variations differed between analyses. In our standard analysis, estimates of pole position and UT1 were make from batches of data approximately of 3 hours duration. The estimated values of the pole position and UT1 for each batch of data are reported at the epoch of the VLBI observation closest to the mid-point time of the batch. Constraints of 0.3 mas and 0.04 mts were placed on the changes between adjacent values of the adjustments to the apriori polar motion and UT1 values. Apriori corrections were made for the tidal coherent variations in pole position and UT1 based on the coefficients given in Herring and Dong [1994]. Residuals to the apriori polar motion and UT1 from this analysis are shown in Figures 1, 2 and 3. As has been shown in numerous pervious studies, the subdaily variations in polar motion and UT1 are dominated by diurnal and semidiurnal variations. Also shown in the Figures 1, 2 and 3 (offset from previous values) are the time variations in the rotation parameters computed from estimates of the cosine and sine terms with periods of exactly 1- and 2-cycles per sidereal day. The estimates of the coefficients used to generate these temporal variations are given in Tables 2 and 3 with the cosine and sine terms defined in Herring and Dong [1994]. For comparison, and offset from the previous values, we show the lower parts of Figures 1, 2 and 3, the temporal variations expected from the tidally coherent model given in Herring and Dong [1994].

To evaluate the sensitivity of our standard stochastic analysis to applying apriori the tidally coherent model to analysis, we repeated the standard analysis with the tidally coherent model removed. The results of this analysis along with the differences between it and the standard analysis are shown in Figures 4, 5 and 6. Visually the types of analysis look very similar although at individual times the differences can be large as 0.9 mas and 0.05 mts. The larger excursions are for points with large uncertainties and most likely result form the filter not being able to track the rapid variations that occur in the diurnal and semidiurnal variations. The root-mean-square (RMS) scatters of the differences between the two analysis are 0.18 mas, 0.14 mas and 0.05 mts for the X and Y pole positions and UT1, respectively. The RMS differences are between 15 and 34% of the standard deviations of the stochastic estimates of the pole position and UT1.

Table 2. Estimates of the cosine and sine components of diurnal and semidiurnal UT1 variations. The time refers to the time of the midpoint of each 24-hour session of VLBI data.

Date	Hr:min	Diurnal				Semidiurnal			
		cos (ms)	± (ms)	sin (ms)	± (ms)	cos (ms)	± (ms)	sin (ms)	± (ms)
7/26	17:58	-0.039	0.013	0.068	0.013	0.004	0.010	0.007	0.008
7/27	20:02	-0.015	0.017	0.021	0.015	0.010	0.012	0.019	0.009
7/28	21:01	-0.053	0.011	0.037	0.007	-0.007	0.007	0.020	0.008
7/28	23:02	-0.032	0.006	0.024	0.004	-0.026	0.004	0.021	0.004
7/30	03:01	-0.048	0.006	0.018	0.006	-0.030	0.005	0.015	0.005
7/30	03:01	-0.040	0.004	-0.008	0.006	-0.032	0.004	-0.003	0.004
7/31	05:59	-0.018	0.032	-0.036	0.038	-0.038	0.024	-0.045	0.022
8/01	09:59	-0.015	0.005	-0.023	0.004	-0.021	0.004	-0.014	0.004
8/02	16:02	0.000	0.004	-0.008	0.005	-0.024	0.005	-0.021	0.004
8/03	20:03	0.037	0.031	0.028	0.017	-0.024	0.015	-0.036	0.015
8/04	21:06	-0.005	0.011	0.033	0.007	0.024	0.007	-0.006	0.009
8/04	23:01	-0.008	0.007	0.041	0.006	0.007	0.006	-0.021	0.005
8/06	03:11	-0.005	0.007	0.033	0.007	0.001	0.006	-0.003	0.007
8/06	03:01	-0.005	0.005	0.043	0.008	-0.009	0.005	0.001	0.005
8/07	06:04	0.005	0.029	0.067	0.030	-0.029	0.020	-0.018	0.018
8/08	10:00	-0.016	0.004	0.036	0.004	0.010	0.004	0.005	0.003
8/09	16:01	-0.004	0.004	0.019	0.004	-0.003	0.004	0.007	0.003
8/10	19:59	-0.035	0.025	0.049	0.014	-0.006	0.012	0.025	0.013
8/11	04:32	-0.020	0.005	-0.003	0.009	-0.016	0.005	0.020	0.007
8/12	03:56	0.036	0.013	-0.054	0.024	-0.007	0.013	0.017	0.014

3. Discussion

In general, the continuity between adjacent VLBI experiments is very good in this analysis although in the figures this agreement can be deceptive because of the large diurnal and semidiurnal signals present in the result. Differences between adjacent days and for the overlapping experiments are less than 0.5 mas for pole position and 0.08 ms for UT1-AT. The largest difference between simultaneous experiments if for the experiments that start on

July 28. While this difference may be related to the coordinates of the stations being in slightly different reference frames, this explanation seem unlikely because the networks used in the simultaneous experiments starting on July 29 are almost identical. (Algonquin Observatory was added to the USNO experiment on July 29, Also the discontinuity from the previous day is for the R&D experiment which used the same network on July 29.). We have investigated the possible effects of azimuthal asymmetry in the atmosphere using the model discussed in Rogers et al. [1993] but estimation of such parameters only slightly reduced (to 0.07 ms) the difference in UT1-AT for the experiments starting July, 28. The gradients estimated at Westford were the largest during this R&D experiment (magnitude corresponding to 80 mm delay at 5° elevation angle) and may indicate that the difference is atmospheric delay related but that the parameterization used in our analysis is not adequate to represent the phenomena.

The other aspect of this data set is the differences between the precision of different VLBI networks to measure high frequency Earth rotation changes. Most of these differences seem related to size and shape of the VLBI networks themselves. The variations in the standard deviations of the diurnal and semidiurnal signals given in Tables 2 and 3 show the amount variation in the current networks. From these tables, there is almost a factor of ten between the smallest and largest deviations of the estimates of these signals.

References

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Table 3. Estimates of the cosine and sine components of diurnal and semidiurnal polar motion variations. The time refers to the time of the midpoint of each 24-hour session of VLBI data.

Date	Hr:min	Retrograde Semidiurnal				Prograde Semidiurnal			
		cos (mas)	± (mas)	sin (mas)	± (mas)	cos (mas)	± (mas)	sin (mas)	± (mas)
7/26	17:58	-0.282	0.201	-0.142	0.215	-0.048	0.213	0.448	0.216
7/27	20:02	0.070	0.249	0.013	0.233	0.521	0.246	0.370	0.253
7/28	21:01	0.270	0.081	-0.076	0.077	0.011	0.085	0.200	0.075
7/28	23:02	0.366	0.088	-0.412	0.091	0.014	0.083	0.036	0.092
7/30	03:01	0.464	0.061	0.108	0.059	0.231	0.064	-0.083	0.055
7/30	03:01	0.435	0.075	-0.241	0.079	0.040	0.077	0.088	0.078
7/31	05:59	0.276	0.332	-0.246	0.276	-0.348	0.271	0.557	0.306
8/01	09:59	0.432	0.069	0.468	0.073	0.086	0.065	-0.080	0.073
8/02	16:02	0.083	0.080	0.478	0.079	-0.108	0.077	0.129	0.081
8/03	20:03	-0.510	0.218	0.261	0.208	-0.202	0.214	0.496	0.223
8/04	21:06	-0.050	0.102	0.116	0.103	-0.026	0.104	-0.012	0.101
8/04	23:01	0.261	0.091	0.411	0.092	0.152	0.089	0.221	0.096
8/06	03:11	-0.040	0.073	0.059	0.067	-0.075	0.071	-0.249	0.065
8/06	03:01	-0.362	0.078	0.253	0.078	-0.080	0.077	0.040	0.082
8/07	06:04	-0.194	0.228	0.101	0.202	-0.001	0.207	0.119	0.216
8/08	10:00	0.083	0.068	-0.067	0.063	0.093	0.062	0.147	0.070
8/09	16:01	0.206	0.075	-0.267	0.070	0.041	0.070	0.002	0.075
8/10	19:59	0.149	0.179	0.049	0.173	-0.130	0.175	0.000	0.195
8/11	04:32	0.163	0.114	0.034	0.120	0.157	0.108	0.092	0.121
8/12	03:56	0.145	0.087	0.154	0.081	0.034	0.084	-0.054	0.080

Date	Hr:min	Prograde diurnal			
		cos (mas)	± (mas)	sin (mas)	± (mas)
7/26	17:58	-0.841	0.290	0.038	0.329
7/27	20:02	-0.037	0.332	-0.229	0.358
7/28	21:01	0.036	0.092	0.316	0.092
7/28	23:02	-0.260	0.103	0.359	0.115
7/30	03:01	0.016	0.060	0.429	0.065
7/30	03:01	0.136	0.106	0.253	0.099
7/31	05:59	0.312	0.406	0.248	0.442
8/01	09:59	0.106	0.085	0.219	0.072
8/02	16:02	-0.145	0.090	0.063	0.092
8/03	20:03	-0.188	0.314	0.410	0.340
8/04	21:06	-0.198	0.132	0.001	0.146
8/04	23:01	-0.168	0.124	-0.392	0.101
8/06	03:11	-0.279	0.074	-0.041	0.075
8/06	03:01	-0.244	0.107	-0.128	0.103
8/07	06:04	-0.691	0.289	0.049	0.313
8/08	10:00	-0.365	0.076	-0.010	0.072
8/09	16:01	-0.133	0.087	-0.026	0.083
8/10	19:59	-0.247	0.267	-0.427	0.297
8/11	04:32	-0.241	0.137	0.173	0.168
8/12	03:56	-0.216	0.130	0.335	0.100

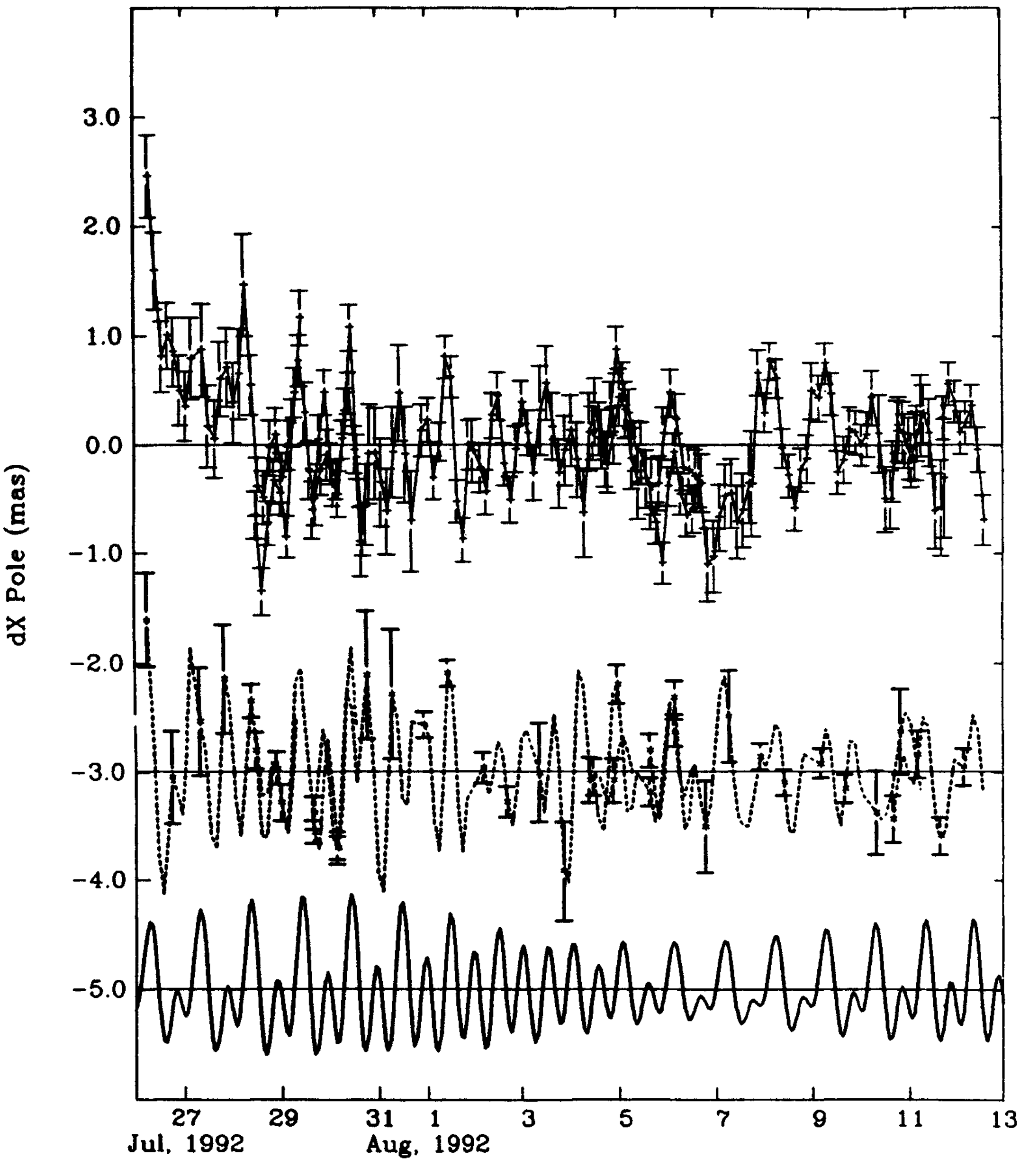

Figure 1. Differences between the stochastic estimates of the X-pole position for the standard analysis discussed in the text (top part of figure). The middle portion of the figure shows with a dashed line the time-domain representation of the diurnal and semidiurnal coefficient estimates (Table 2). Occasional one-standard deviation error bars are shown computed from the standard deviations of the coefficient estimates. The lower part of the figure shows the time domain representation of the tidally coherent signals given in Herring and Dong [1994]

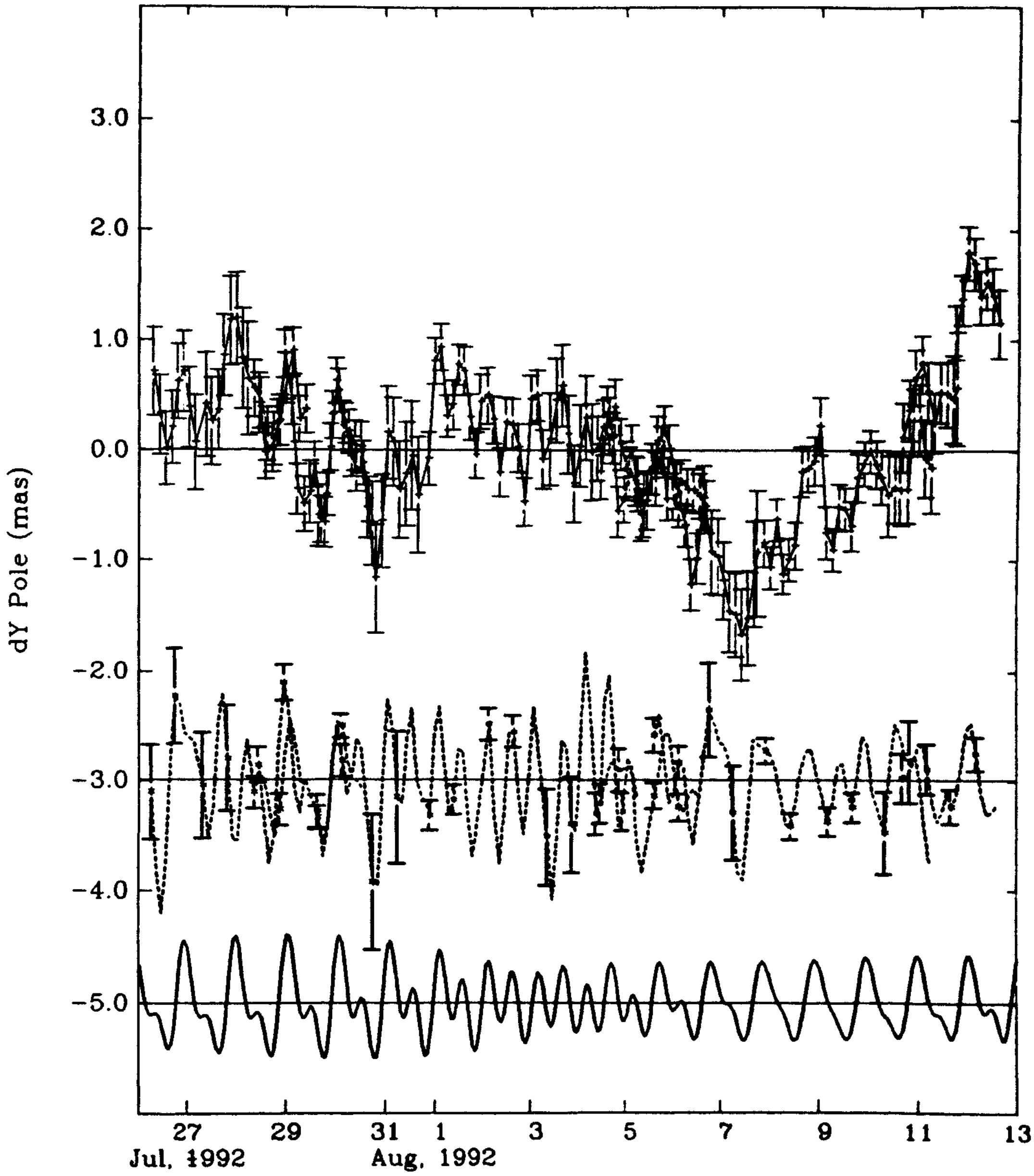

Figure 2. Same as Figure 1 except Y-pole position differences are shown.

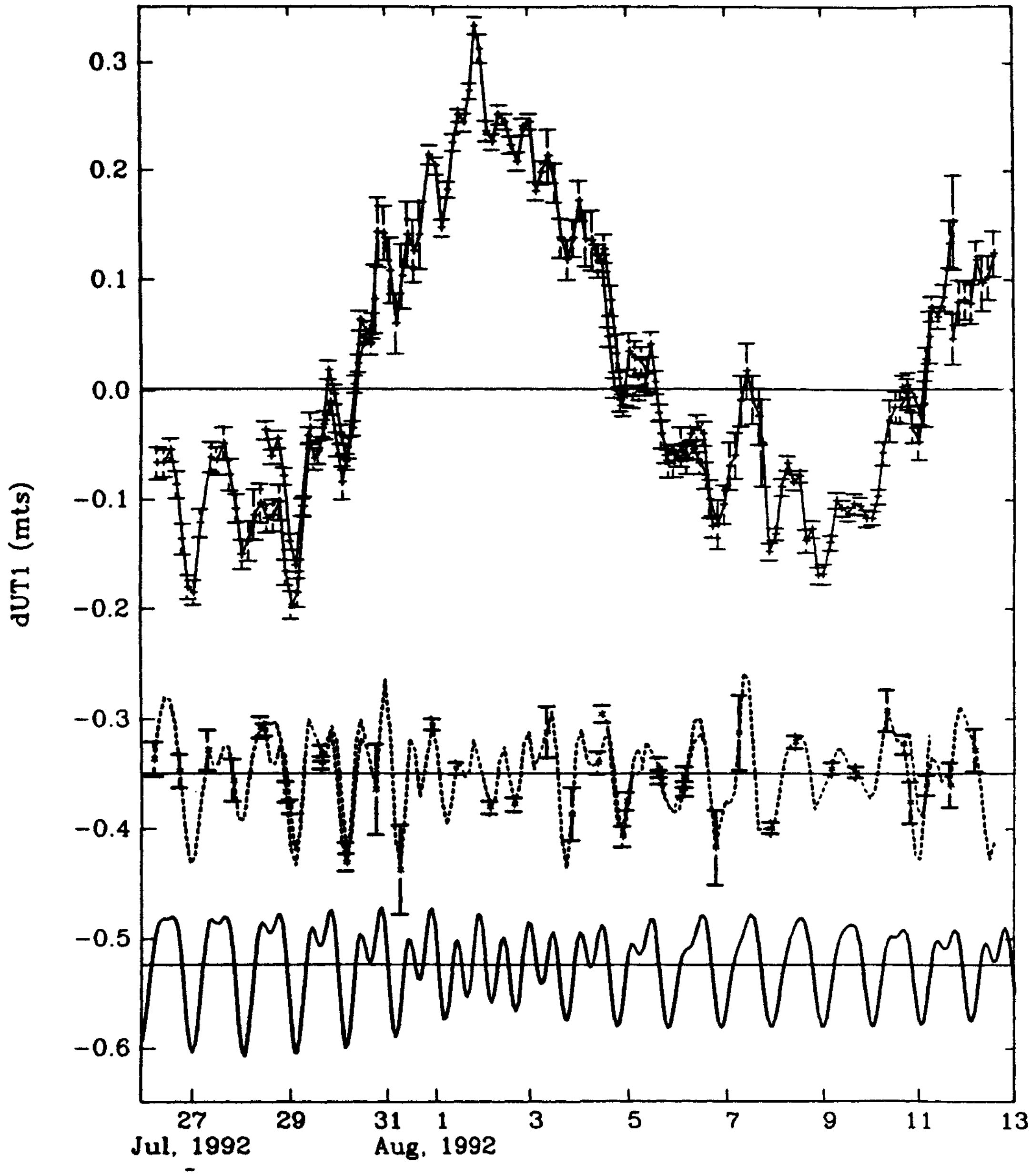

Figure 3. Same as Figure 1 except UT1-AT differences are shown.

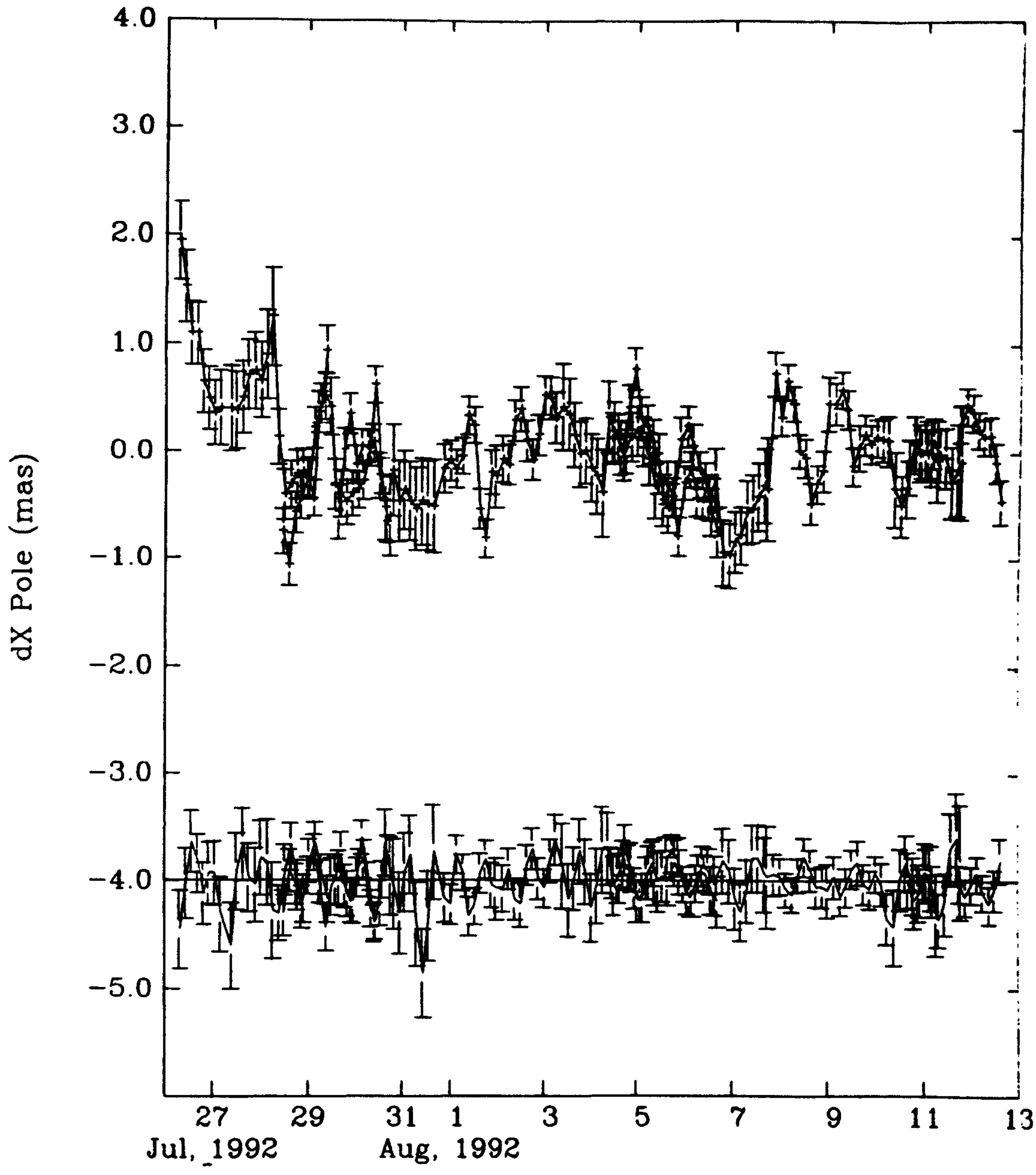

Figure 4. Differences between the stochastic estimates of the X-pole position for the standard analysis discussed in the text except that no diurnal and semidiurnal polar motion and UT1 variations were applied apriori (top portion of figure). The lower portion the differences between the standard analysis and this analysis are shown. Most of the differences can be explained by the stochastics not being able to track the rapid variations in the diurnal and semidiurnal signals when the VLBI data geometry is weak.

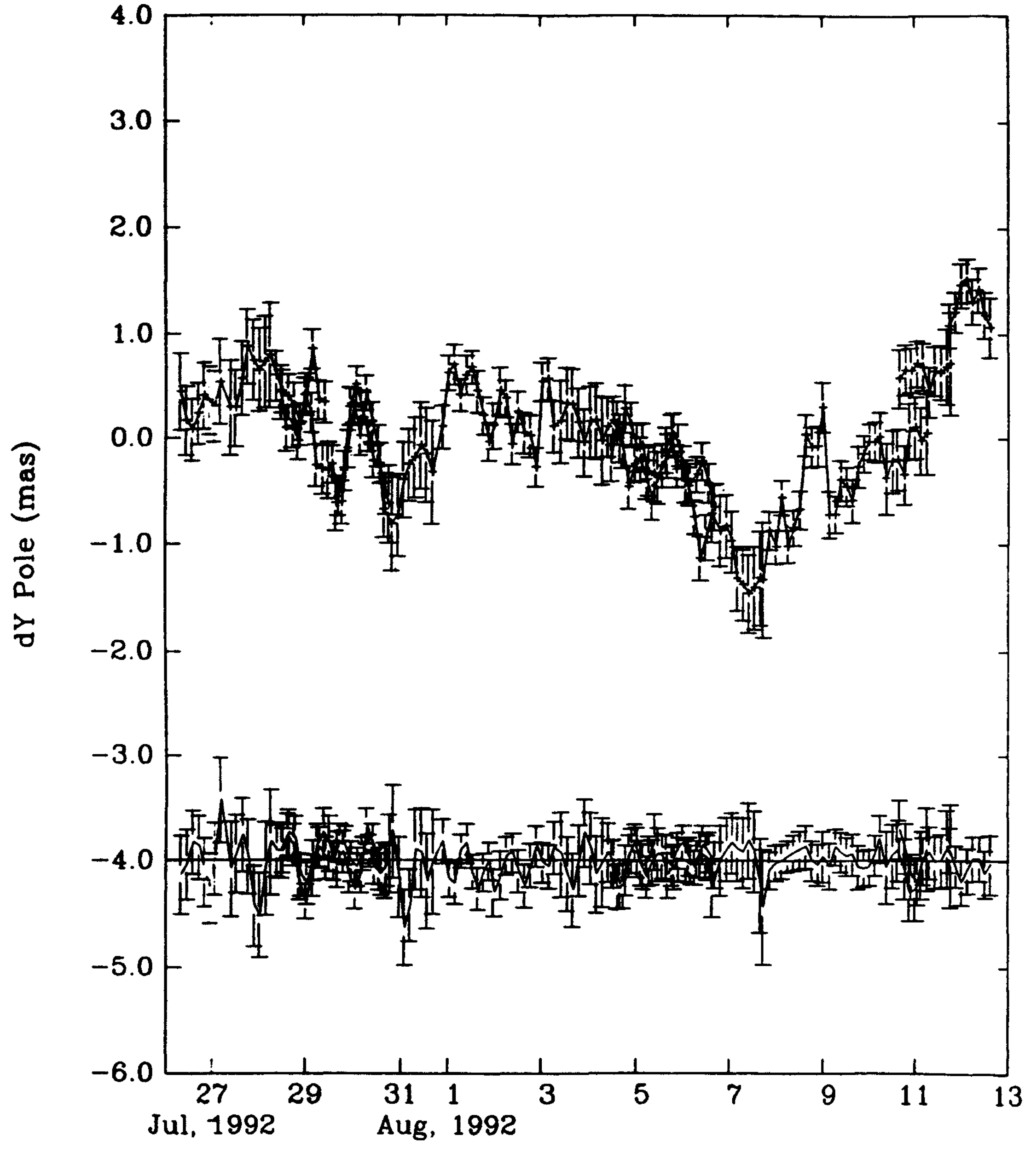

Figure 5. Same as Figure 4 except Y-pole position differences are shown.

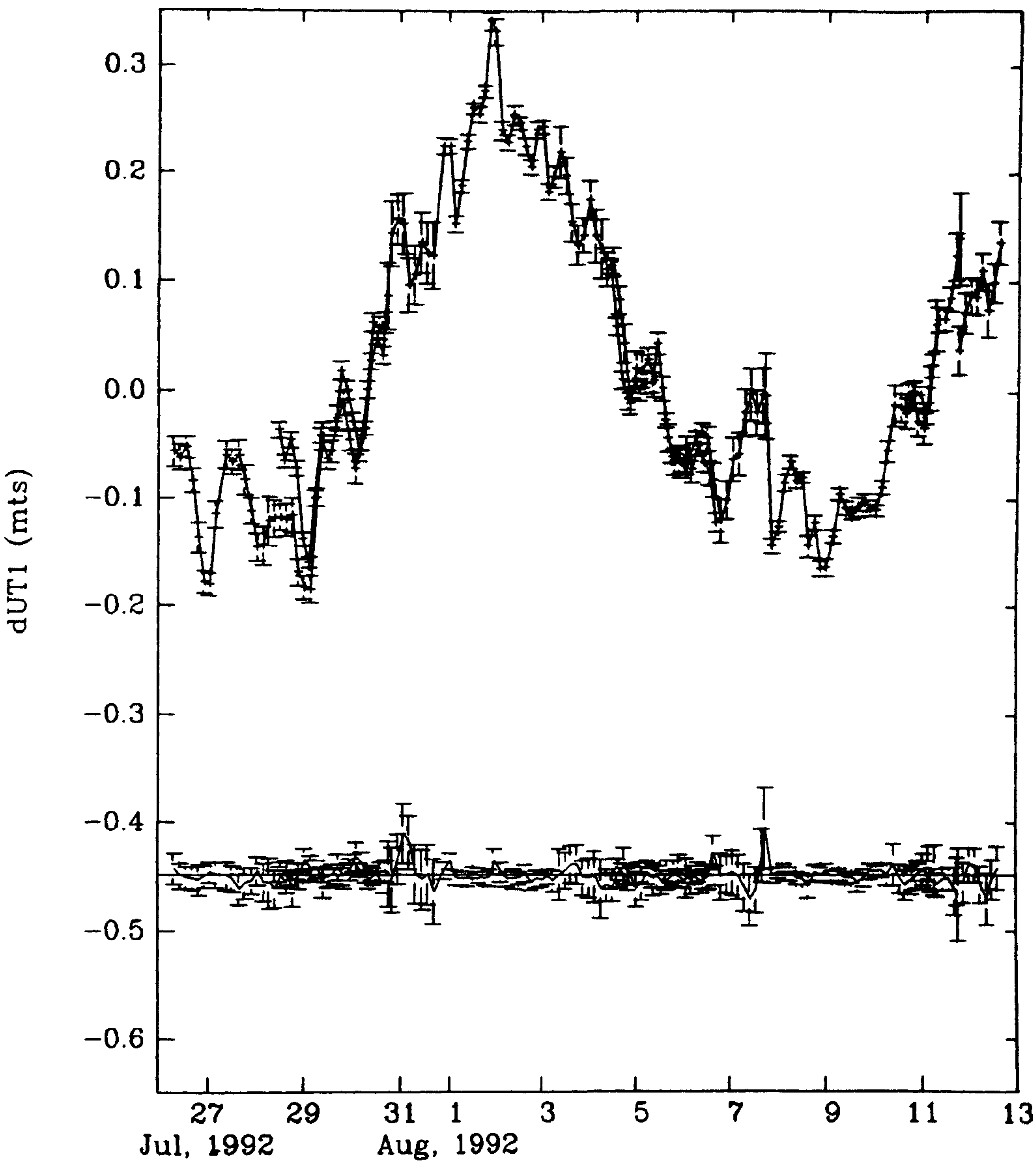

Figure 6. Same as Figure 4 except UT1-AT differences are shown.