PREDICTING UNIVERSAL TIME FROM ASTRONOMICAL AND METEOROLOGICAL MEASUREMENTS

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ABSTRACT. Autoregressive prediction filters are tested on stationarised time series of UT1-TAI and of accumulated values of the duration of the day derived from the axial atmospheric angular momentum.

1. INTRODUCTION

In this paper, we have investigated a statistical approach based on autoregressive processes for predicting Universal time. Two data sets were available for testing various prediction procedures.

- The series of UT1-TAI at five-day intervals obtained by the BIH from a combination of results of VLBI, optical astrometry and lunar laser ranging. Over the years 1979-1985, this solution is progressively dominated by the VLBI results. The formal uncertainty of a single determination of UT1 decreases from 0.0007s in 1979 to 0.00005s in 1985. In the present study, the effect of zonal tides is removed for all periods using the model of Yoder et al. (1981) ; the corrected values of universal time are denoted UT1F.

- A series describing the part in the variations of universal time due to the atmospheric excitation, denoted UT1A. This series was obtained by accumulating the daily values of the duration of the day derived from the atmospheric angular momentum (Barnes et al. 1983). It is sampled at five-day intervals.

We have also considered the series of differences UT1D = UT1F-UT1A at five-day intervals. This series represents the sum of the variations of UT1 due to non-atmospheric excitation, and of the errors in the two series differenced.

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2. THE SPECTRUM OF VARIATIONS IN UNIVERSAL TIME

Low frequency (under one cycle/year)

The spectrum of universal time is dominated by the seasonal variation of atmospheric origin. When this oscillation is filtered out, lower frequency variations with a large amplitude are still present. These variations are shown in figures 1a and 1b over the years 1980 through 1985 for universal time and for atmospheric series. The variations shown are similar, which indicates that they are largely due to the atmospheric excitation, as already shown by Eubanks et al.(1986). However, the series of differences (figure 1c) shows significant residual variations, with a total amplitude of 0.005s.

Seasonal variations

It is well known that the annual and semi-annual components of the seasonal variations in UT1, with respective approximate amplitudes 0.02s and 0.01s have interannual variations of up to 50%. Moreover, the differenced series UT1D shows also interannual variations for these frequencies (Table 1).

Table 1. Seasonal variations in the "non atmospheric" variations of universal time UT1D (in ms), expressed as

$$b \sin 2\pi t + c \cos 2\pi t + d \sin 4\pi t + e \cos 4\pi t, \ t \text{ in years}$$

Time span	b	c	d	e	uncertainty	rms residual
1980.2 - 1981.4	-0.1	-3.1	+1.0	-1.0	0.1	0.9
1981.4 - 1982.6	+2.3	-2.3	+1.4	-2.2	0.2	1.2
1982.6 - 1983.8	-2.0	+2.6	+1.8	-2.5	0.2	1.3
1983.8 - 1985.0	+2.9	+5.2	+3.0	-0.9	0.2	1.0

High frequency (over two cycles/year)

The existence of transient variations with recurrence times of 20 to 120 days due to the atmospheric excitation is well established (Anderson et al. 1984, Feissel and Nitschelm 1985). The spectra of UT1F and UT1A over 1980-1985 are shown in figures 2a and 2b. A noticeable structure of the UT1A spectrum is the apparent extinction of oscillations for periods under 25 days, which is the cause of a relatively high level in these frequencies for UT1D (spectrum of figure 2c). A pair variance study of the time series suggests that for UT1F as well as for UT1A the high frequency spectral density follows a law of random walk, whereas the UT1D spectrum follows a flicker noise law.

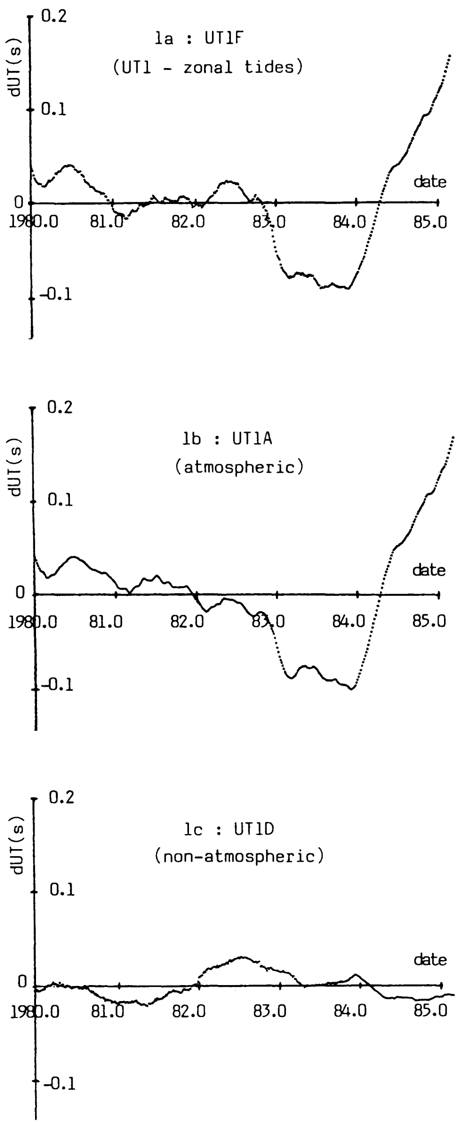

Figure 1. Low frequency variations in universal time (seasonal terms and linear drifts substracted).

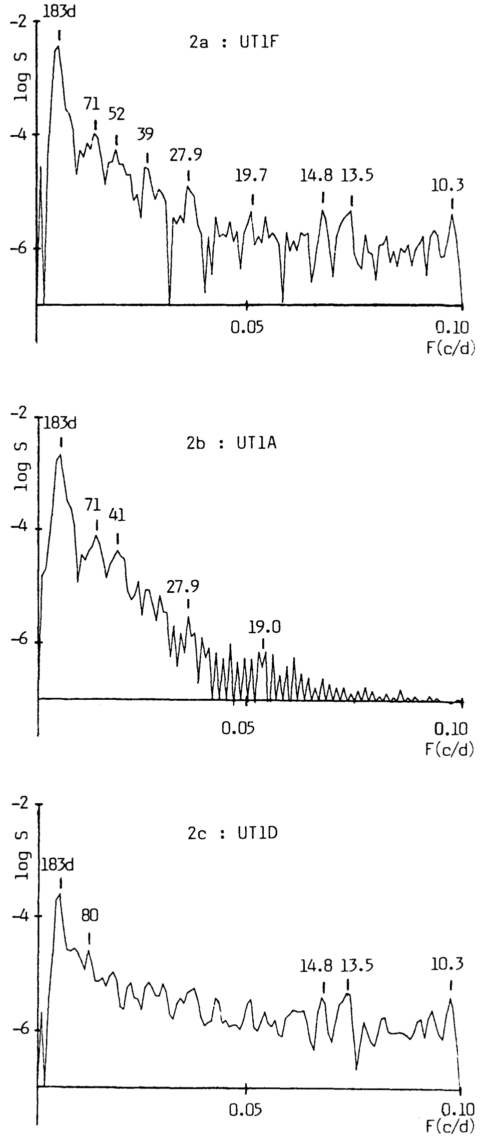

Figure 2. High frequency spectrum of universal time (periods longer than 190 days smoothed out).

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3. STATIONARISATION AND PREDICTION OF SERIES OF UNIVERSAL TIME

Method

The first step aims at removing the low frequency variations from the series (UT1F, UT1A, UT1D), by a trend and a seasonal term (annual and semi-annual).

Tests with more complete models, such as a quadratic expression or recurrent variations at higher frequencies than two cycles/year, were performed. They do not lead to any improvement of the prediction. The main difficulty arises from the interannual variability of the seasonal atmospheric oscillation. To investigate the consequences of this effect, several spans of past data, ranging from 450 to 1100 days, were used to stationarise the series.

In the second step, the coefficients of autoregressive filters are adjusted in the residual series, for orders one through five (5 to 25 days). Two predictions are performed, 1. by selecting the order corresponding to the last significant coefficient (optimal prediction), and 2. by averaging the predictions with the filters of orders one to five (mean prediction). The predicted values are then added to the low frequency part determined in the first step, and the result is compared to the real data, for lead times of 10 and 40 days.

The prediction capability of the filters is expressed as the probability that the absolute value of the prediction error for a given lead time be lower than an a priori limit. The limits chosen are 0.003s for a lead time of 10 days (P_{10}) and 0.010s for a lead time of 40 days (P_{40}). With this definition, the prediction capability of the prediction circulars of BIH and USNO are at the level of 0.75. It should be remarked that in the above described process, there is no attempt to predict the short term oscillations of UT, except for those due to zonal tides; as a result, the maximum value of P_{10} is 0.93, i.e., the probability of having short term oscillation larger than 0.003s is 0.07.

Data analysis

The predictions are performed independently on the three series UT1F, UT1A and UT1D, based on 35 consecutive months from January 1982 through November 1984. In each case, spans of past data of 450, 550, 750 and 1100d are considered. The results obtained are listed in Table 2.

The best predicted series is UT1D ("non-atmospheric" variations). Its spectrum is characterised by small low frequency variations and a relatively high level of noise in high frequencies. The atmospheric series (UT1A), which spectrum is characteristised by large low frequency variations and low level of noise in the high frequency, is not so well predicted. The variability of the seasonal term is probably the source of inaccuracy in the prediction. The lowest prediction capability is for the series UT1F, which spectrum is the less favorable of the three.

Table 2. Prediction capability of the optimal and the mean predictions for different past data spans.

Past	2a:UT1F				2b:UT1A				2c:UT1D			
	optimal		mean		optimal		mean		optimal		mean	
	P_{10}	P_{40}	P_{10}	P_{40}	P_{10}	P_{40}	P_{10}	P_{40}	P_{10}	P_{40}	P_{10}	P_{40}
450d	.60	.56	.67	.70	.69	.77	.16	.83	.80	.99	.83	.97
550d	.63	.56	.78	.74	.76	.76	.81	.81	.81	.89	.81	.89
750d	.56	.59	.78	.81	.74	.83	.72	.86	.83	.89	.83	.89
1100d	.52	.48	.70	.70	.79	.88	.75	.83	.91	.83	.64	.75

Note. The maximum possible value of P_{10} is 0.93.

4. CONCLUSION

The accuracy of predictions of universal time can be limited by two characteristics of its spectrum. Under a 10-day lead time, the limitation is due to the short term noise in the UT1 spectrum. The intrinsic noise of UT1 sampled at 5-day intervals, as measured by the pair variance, is at the level of 0.0007s. Since the introduction of SLR, LLR and VLBI in the Earth rotation series, the measurement noise at 5-day intervals is inferior to 0.0001s, therefore it introduces no limitation in the prediction capability. The second aspect which limits the accuracy of prediction is the variability of the seasonal oscillations under the atmospheric excitation. Improvements in this respect can be expected from better fitted prediction of this term (Feissel et al. 1986). This source of inaccuracy is dominating for predictions with lead times over 10 days.

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