Short-period variations of the Earth rotation parameters as seen by VLBI

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Abstract

Modern geodetic VLBI experiments provide very accurate results of polar motion and UT1-UTC. More than 300 VLBI experiments (NEOS-A from 1993 till 1998, CONT'96, CORE) were analysed by the OCCAM 3.4 VLBI software using the least-squares collocation method (LSCM). The LSCM allows to estimate the Earth rotation parameters with a temporal resolution of 3-7 minutes. Wavelet transformations of the UT1-UTC and polar motion time series obtained by the VLBI solutions were done. Several irregular quasi-periodic variations were found besides the well known diurnal and semidiurnal periods. In many UT1-UTC data sets periods around 8 hours and between 5 and 7 hours can be seen. The results of two parallel VLBI sessions which took place since 1998 were compared in the high-frequency range. The wavelet analysis reveals interesting patterns in polar motion, too.

1. Introduction

The geodetic and geophysical interest in VLBI is based on the use of a quasi-inertial reference frame formed by a set of compact extragalactic radio sources. VLBI measures very accurately the angles between the Earth-fixed baseline vectors and the directions to the space-fixed radio sources. Thus, even the most subtle changes of the baseline lengths and of the baseline directions with respect to the inertial system can be detected. Geodynamical phenomena such as polar motion, Universal Time (UT1) variations, precession and nutation, Earth tides, ocean tidal response, and tectonic plate motions can be monitored with highest accuracy.

The UT1 variations are dominated by the seasonal terms, an annual and a semiannual oscillation; but there is also a rich spectrum of tidally induced short-period oscillations (Yoder et al., 1981), which could be seen by VLBI due to its increasing accuracy from mid of the eighties (Robertson et al., 1985; Campbell and Schuh, 1986). Even the short-period tidal influences of the oceans (Brosche et al., 1989) could be detected in the VLBI measurements by analysing a large number of observing sessions (Brosche et al., 1991). Today, a very high temporal resolution of the Earth rotation parameters can be achieved by VLBI using the least-squares collocation method (LSCM) (Titov, 1998). It allows to estimate the Earth rotation parameters every 3-7 minutes. This paper concentrates on short-period variations of the Earth rotation parameters which can be seen when analysing the VLBI results.

2. Earth rotation parameters observed by VLBI

More than 300 VLBI experiments (NEOS-A from 1993 till 1998, CONT'96, CORE) were analysed by the OCCAM 3.4 VLBI chosing the LSCM approach. Figure 1 shows UT-UTC1 parameters determined during five days of the VLBI campaign CONT in September 1996. In general there is a good agreement between the results obtained within this study and other VLBI solutions, e.g. the US Naval Observatory (USNO) hourly estimates. From the whole data set, i.e. from more than 300 sessions, the amplitudes of the main diurnal and semidiurnal UT1 variations due to the ocean tides were determined (Titov, 1998). They agree well with other empirical models, e.g. those given in the IERS Conventions (1996). After the ocean tidal influences were removed from the observed UT1-UTC series, the residuals offer the opportunity to search for even smaller variations in the rotation of the Earth. Those are supposed to be due to resonances with modes of the Earth or due to excitation by Earthquakes. Also the VLBI polar motion data sets provide the opportunity to investigate the very short periods.

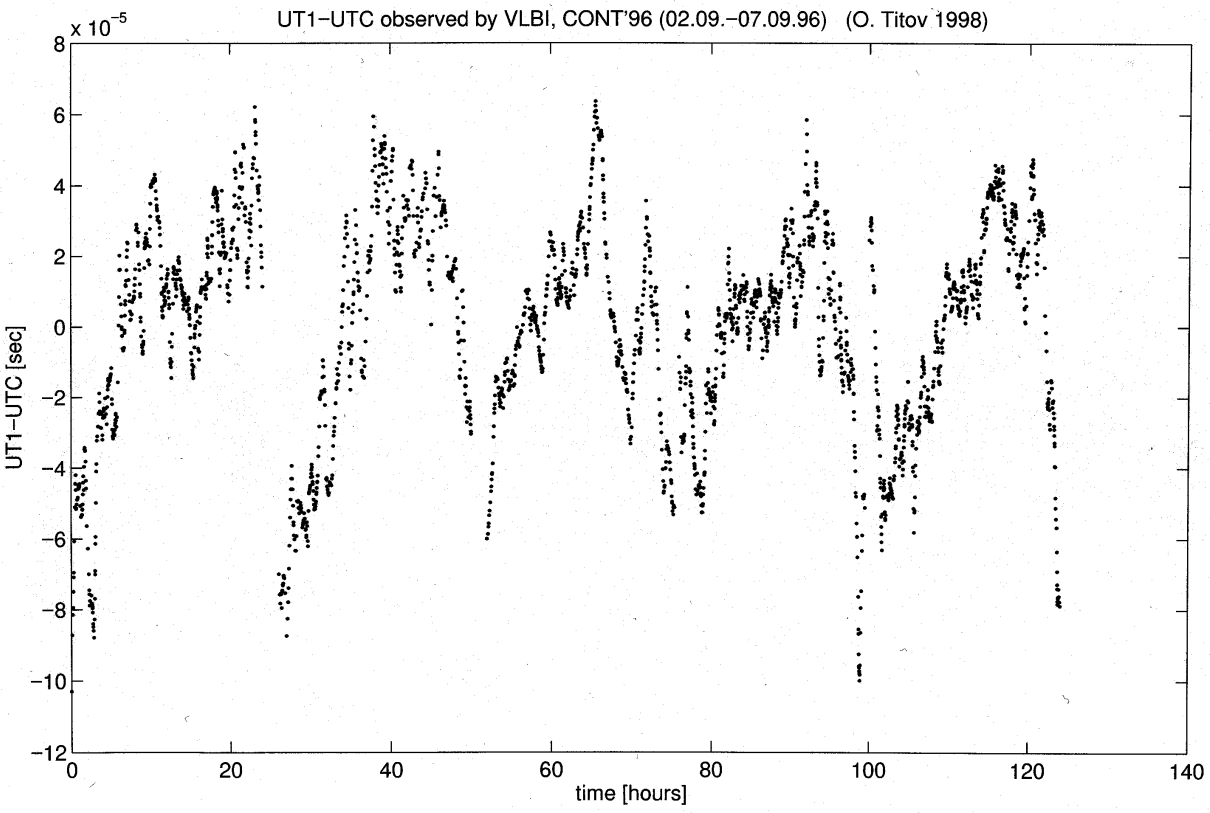


Fig. 1: UT1-UTC parameters with high temporal resolution determined during five days of the VLBI campaign CONT in September 1996.

3. Wavelet analysis of Earth rotation parameters

There are several remarkable advantages of the wavelet transform, which was introduced by Grossmann and Morlet (1984), in comparison with 'classical' methods based on the Fourier transform. In the wavelet transform, the harmonic oscillation is replaced by a wavelet function which is adapted to the signal to be analysed by shifting it along the time axis and scaling it along the frequency axis. It allows the time localization of an unstable quasi-periodic signal within a given data set. Hence, the wavelet transform is an excellent tool for analysing signals with time-varying amplitudes and/or periods.

Many of the high-resolution UT1-UTC data series and polar motion data series obtained by the VLBI solutions were analysed with respect to periodic variations. First, the main diurnal and semidiurnal variations due to the ocean tides were removed using the IERS Conventions (1996) correction model. Then, the wavelet transformation was applied. Although ocean tidal influences had been already corrected, many of the wavelet spectra of the UT1 series show residual energy in the diurnal and semidiurnal period range. This can be due to different reasons:
1. The IERS Conventions (1996) correction model is not good enough. It contains only the big diurnal and semidiurnal terms but neglects the smaller ones.
2. The ocean tidal influences on the rotation of the Earth are variable with time for each tide, i.e. they cannot be described by simple trigonometric functions with constant amplitudes and phases. Due to interactions between the ocean currents and the ocean tides it is rather likely that the ocean models have to become refined in the future.
3. There are other influences than ocean tides on the rotation of the Earth with diurnal and semidiurnal periods. These could be caused by the atmosphere for instance.

Additionally, most of the datasets revealed irregular quasi-periodic fluctuations, very often at 20 hours and 40 hours and also with extremely short periods, e.g. around 8 hours, between 5 and 7 hours and even down to 2 to 3 hours. After having subtracted the main ocean tidal terms from the CONT 1996 UT1-UTC series the wavelet spectrum was computed. In figure 2 it is plotted for very short periods below 10 hours.

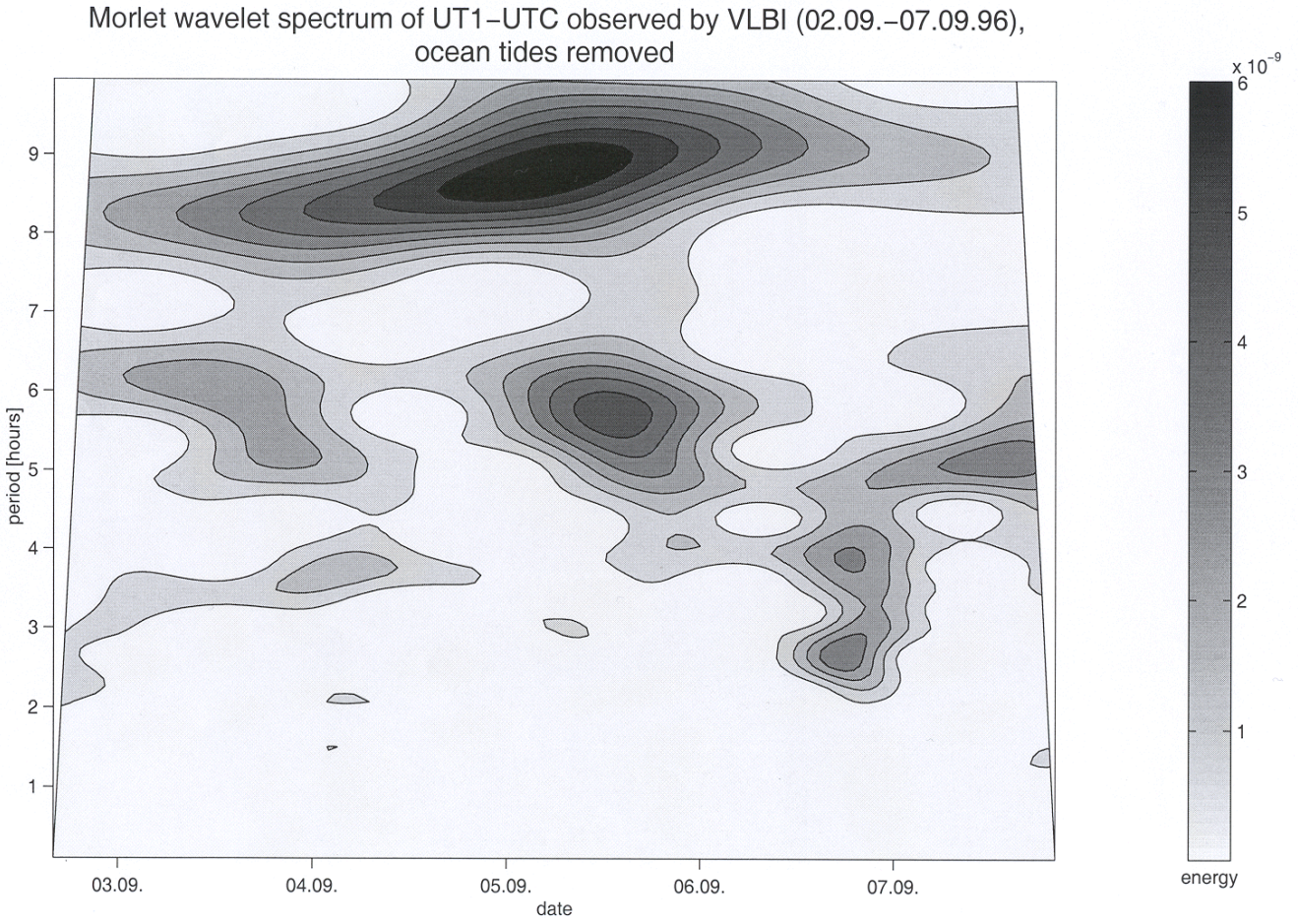


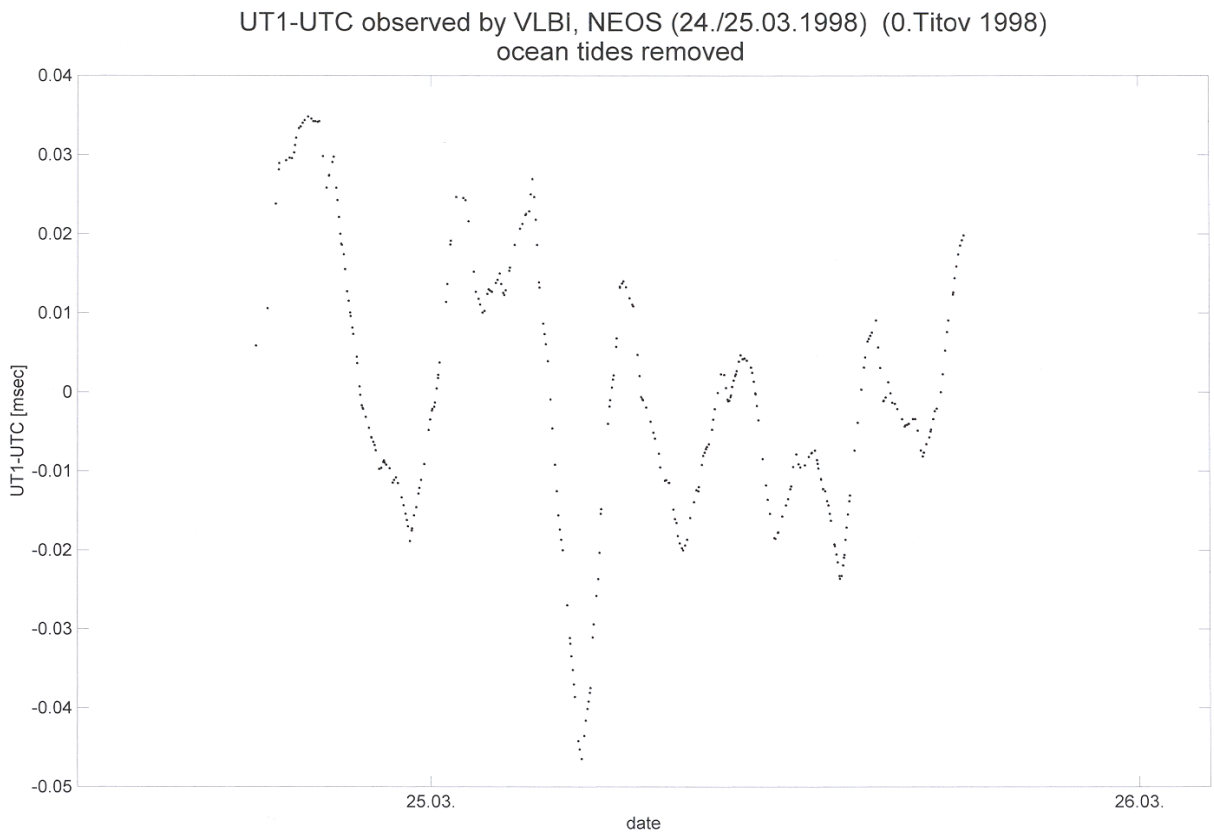
Fig. 2: Wavelet spectrum for periods below 10 hours of the high resolution UT1-UTC series shown in figure 1 (ocean tidal terms removed)

Parallel sessions on different VLBI networks which took place since 1998 offer the opportunity for independent observations of the Earth rotation and hence the wavelet spectra should contain the same variations of the Earth rotation parameters. Figures 3a,b show the results obtained by the VLBI NEOS-A network (Green Bank - Fortaleza - Kokee - Ny Alesund - Tigo) and the CORE-A network (Fairbanks - HartRAO - Hobart - Matera - Westford - Algonquin Park); both started from March, 24th, 1998, 18.00 to observe simultaneously for 24h (NEOS-A256 and CORE-A032). It should be noted that the two networks form two completely different VLBI 'observing systems', i.e. different radiosources were observed by different stations. As we are mainly interested in the short-period variations a comparison in the frequency domain was carried out. Figures 4a,b show the wavelet spectra of the UT1-UTC series obtained by the two VLBI sessions: both agree rather well - in particular a dominant variation around 8 hours can be seen which decreases in the second part of the sessions. As these are the only parallel VLBI sessions which have been analysed so far, further comparisons have to be done.

The VLBI solutions using the LSCM yielded also high-resolution polar motion series. These were analysed as complex values by the wavelet transformation. The wavelet spectra revealed irregular prograde and retrograde short-period fluctuations in polar motion, again very often around 8 hours and even with shorter periods, e.g. at 5-7 hours.

4. Conclusions

VLBI is unique in its ability to monitor without hypotheses *all* components of Earth orientation. The results of VLBI experiments can be used for scientific research in many areas, such as: tidal deformation of the solid Earth and oceanic and atmospheric tidal loading, excitation of UT1 and polar motion down to periods of a few minutes, investigations of the Earth interior and improvements of the terrestrial reference frame. The Earth rotation data observed by VLBI have begun to reveal hitherto unseen phenomena. Irregular quasi-periodic variations can be seen in the wavelet spectra besides the well known diurnal and semidiurnal periods. Possible excitation mechanisms for the observed variations of the Earth rotation parameters such as terdiurnal variations, the free oscillations of the oceans (10h, 20h, 40h, 50h), atmospheric modes and resonances with free oscillations of the Earth (e.g. the Slichter mode) are under discussion. Careful tests have to be done to check the significance of such tiny variations. In particular, correlations with meteorological parameters at the observing stations are going to be investigated.



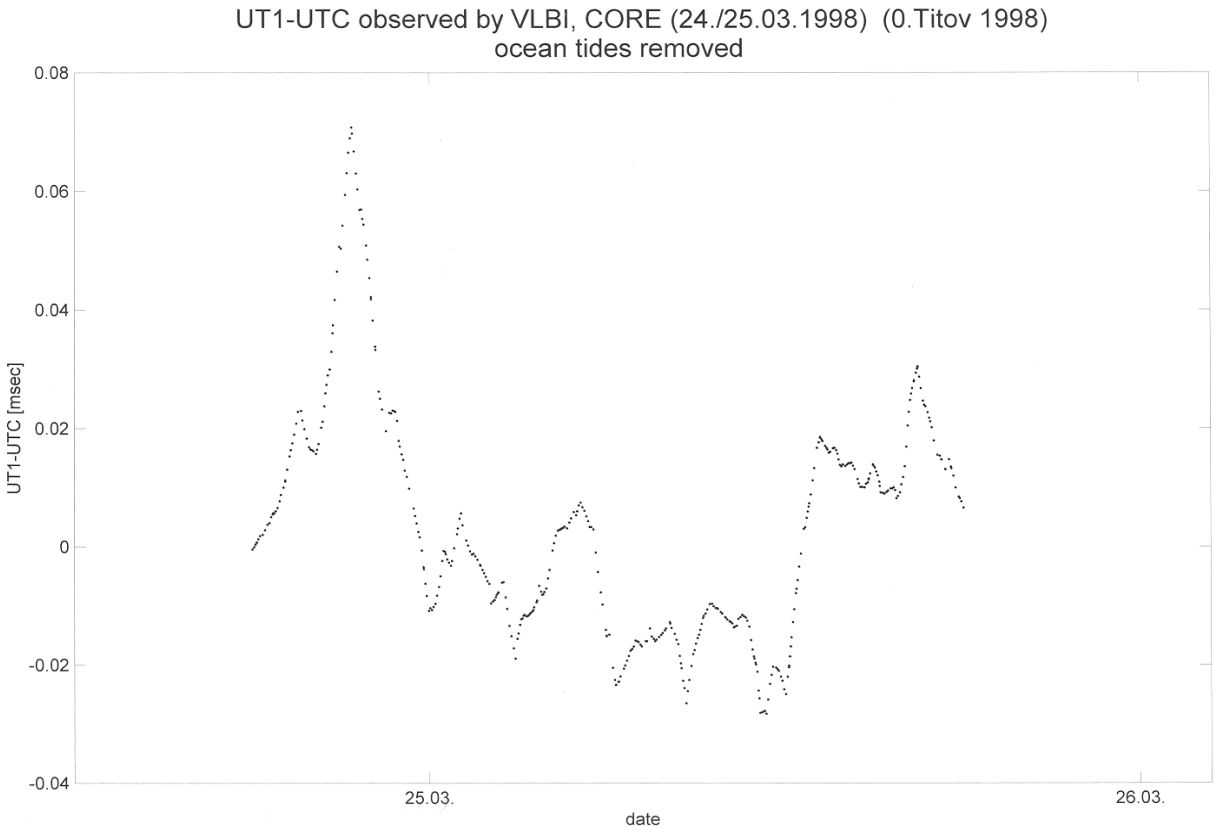


Fig. 3a,b: UT1-UTC parameters with high temporal resolution determined by two parallel VLBI sessions starting on March 24th, 1998 (lower plot: CORE-A032, upper plot: NEOS-A256)

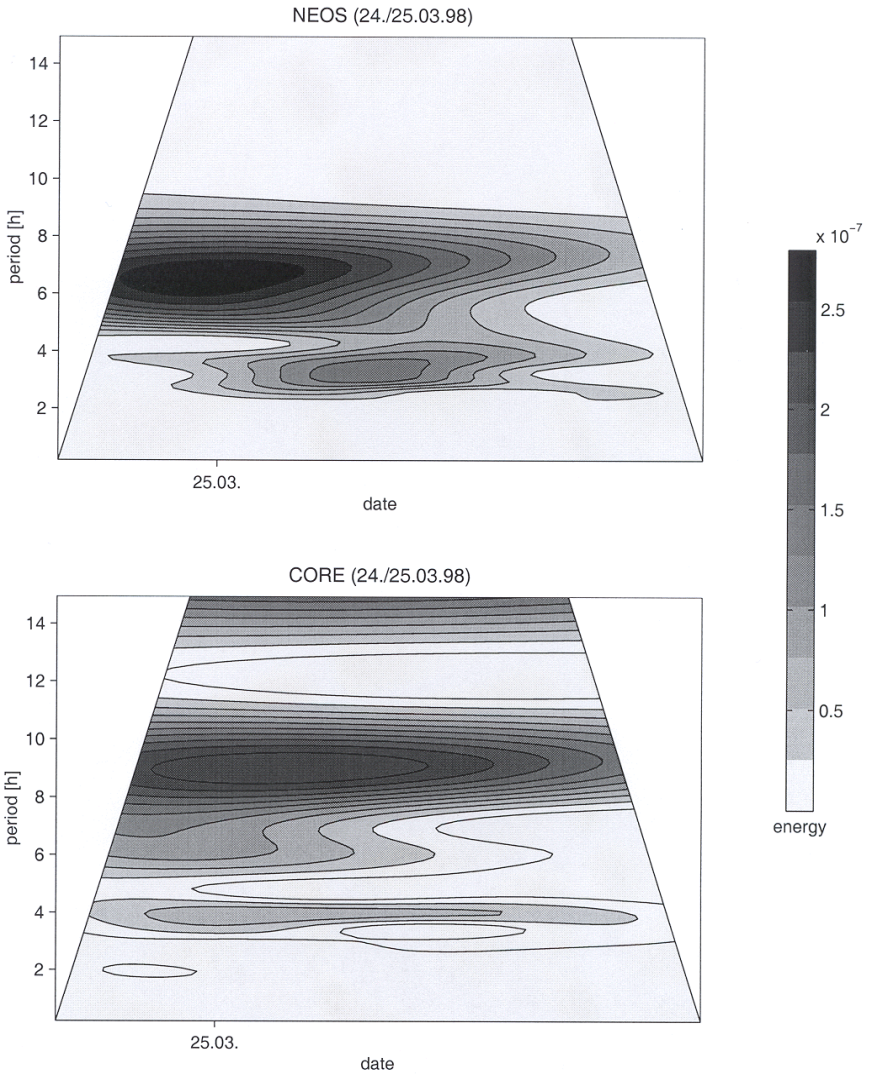


Fig. 4a,b: Wavelet spectra for periods shorter than 15 hours of the the two time series shown in figure 3a,b

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