COMPARISON BETWEEN THE FOURIER TRANSFORM BAND PASS FILTER AND THE WAVELET TRANSFORM SPECTRO-TEMPORAL ANALYSES ON THE EARTH ROTATION PARAMETERS AND THEIR ATMOSPHERIC EXCITATION FUNCTIONS

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ABSTRACT

In this paper the three spectro-temporal analyses: the Fourier Transform Band Pass Filter (FTBPF), the Wavelet Transform (WT) and Harmonic Wavelet Transform (HWT) are compared on short period Earth Rotation Parameters (ERP) and the Atmospheric Angular Momentum (AAM) data. The computed time variable and time-frequency spectra of length of day (LOD) data reveal various effects of changing the time and frequency resolution in the FTBPF and frequency resolution in the HWT spectra.

TIME VARIABLE FTBPF AND TIME-FREQUENCY HWT/WT SPECTRA AND COHERENCE

Short period oscillations in the ERP data have variable amplitudes and corresponding spectra depend strongly on data time span. Thus, spectro-temporal analyses are necessary. In the WT the time series is transformed into time-frequency domain by computing convolution with a dilated analysing function e.g. Morlet wavelet, Mexican hat etc. (Chui 1992, Popiński and Kosek 1994). The WT moduli represent time-frequency spectra and are functions of instantaneous amplitudes of oscillations (Chui 1992). In the Morlet wavelet the σ parameter can be introduced which directly controls the time-frequency resolution of the relevant WT.

The FTBPF enables computation of time variable spectrum and coherence in which changing of time and frequency resolution is possible (Kosek 1995, Popiński and Kosek 1995a, 1995b, Kosek et al. 1998, Kosek and Popiński 1999). The square root of time variable FTBPF spectrum is proportional to the instantaneous amplitudes of oscillations.

In the HWT the frequency resolution can be changed by applying harmonic wavelets with localised spectral windows defined by the central frequency and the frequency bandwidth (Newland 1998). The HWT enables improving frequency resolution of a spectrum in comparison to the WT. In time-frequency analysis by the HWT the WT coefficient of a signal is defined by the convolution of this signal and the complex-valued harmonic wavelet function localised in frequency domain. In practice the FFT of a time series is multiplied by the FT of the harmonic wavelet function, which is of boxcar type possibly tapered by the gaussian window for better frequency resolution. Next, applying the inverse FFT, we estimate the magnitude of the wavelet transform coefficients representing time-frequency spectrum dependent on the two parameters: the window halfwidth λ and smoothing parameter σ (Newland 1998). The HWT time-frequency coherence estimates the correlation between the HWT coefficients of two time series (Kosek and Popiński 1999).

DATA AND THEIR ANALYSIS

In this paper the following time series were used:

1) The ERP (x, y pole coordinates and LOD) IERSC04 data in 1962.0 - 1999.3 years with 1-day sampling interval (IERS 1998),
2) the equatorial and axial components χ^{w+p+ib} of the atmospheric angular momentum (AAM) reanalysis data in 1958.0 - 1999.3, computed by the National Center for Environmental Prediction / National Center for Atmospheric Research (NCEP/NCAR), being the sum of the wind and pressure modified by inverted barometric correction (Salstein et al. 1993), the sampling interval is equal to 0.25 days.

From the LOD IERSC04 data tides were removed according to the IERS Conventions (McCarthy 1996) and next they were filtered by the Butterworth high pass filter (HPF) (Otnes and Enochson 1972) with the 270-day cutoff period to remove longer period oscillations. Next, the time variable and time-frequency spectra of such filtered LOD data were computed using the FTBPF, WT and HWT (Fig. 1).

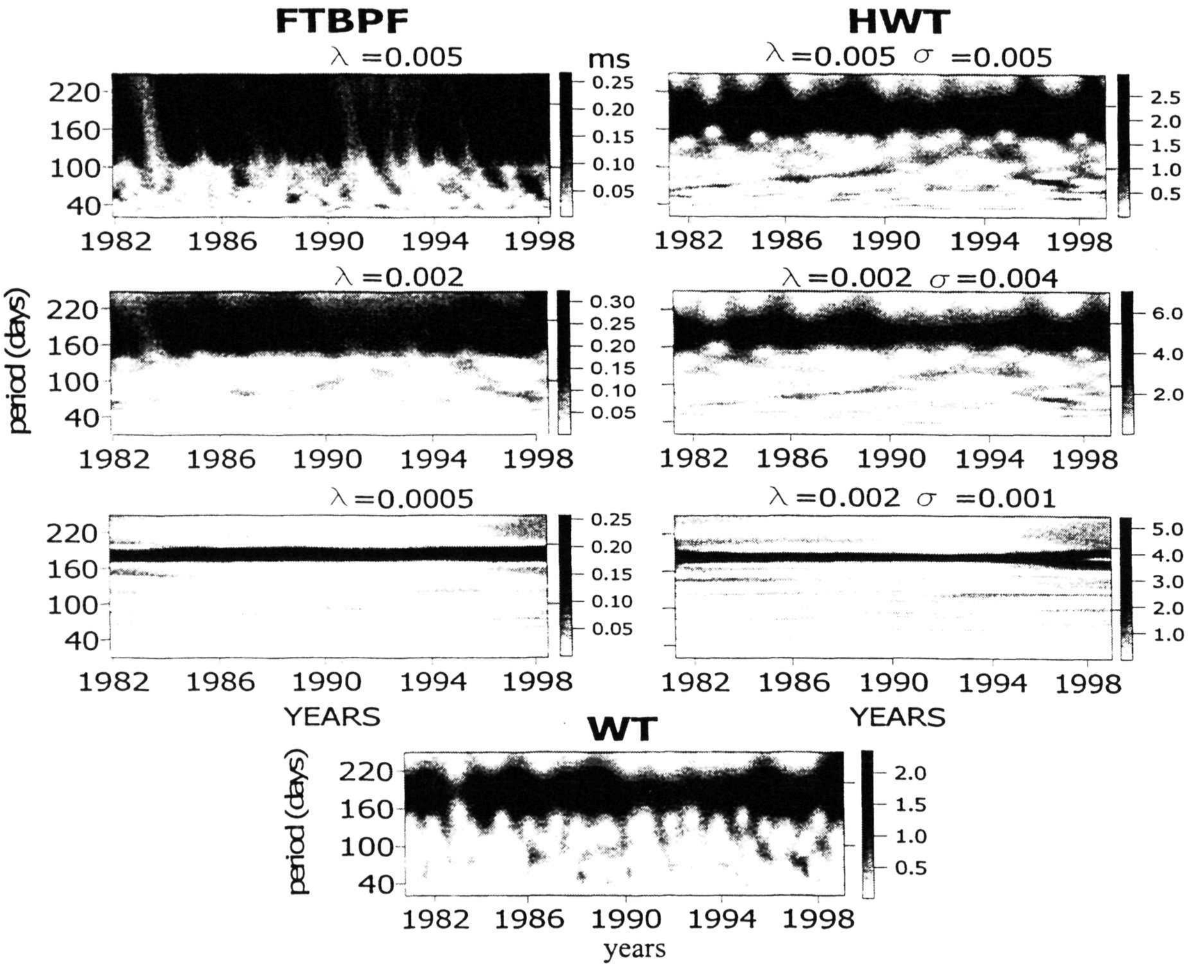

Fig. 1. Time variable FTBPF amplitude spectra, the HWT time-frequency spectra with different parameter values and the WT spectrum (Morlet wavelet) of the LOD IERSC04 data filtered by the Butterworth HPF with 270-day cutoff period.

In the FTBPF time variable and the HWT time-frequency analysis methods it is possible to increase the frequency resolution, however, in the case of the FTBPF it's also possible to increase the time resolution by increasing the λ parameter. It can be seen that decrease of the λ parameter in the FTBPF or λ and σ parameters in the HWT increases the frequency resolution of time variable and time-frequency LOD spectra. Decrease of the λ parameter in computation of the FTBPF amplitude spectrum results in decreasing the computed amplitude values. The spectra reveal that in LOD data there is semi-annual oscillation of non-tidal origin with the amplitude of the order of 0.3 ms. Decrease of the λ parameter enabled resolving the semi-annual and semi-Chandler oscillations in polar motion data (Kosek and Popiński 1999).

The atmospheric influence on the ERP is described by the equatorial and axial components of the Effective AAM excitation function χ_1, χ_2, χ_3 (Barnes et al. 1983). This atmospheric excitation function can be compared with the geodetic excitation function ψ_1, ψ_2, ψ_3 which were computed from the IERS EOPC04 data (IERS 1998), where and ψ_1, ψ_2 were computed by Wilson and Haubrich (1976) deconvolution formula and $\psi_3 = -LOD$. Comparison of the atmospheric and geodetic excitation functions can be performed by computing the coherence which shows the influence of the AAM excitation functions on the ERP as a function of a frequency or period. The coherences between $\chi_1 + i\chi_2$ and $\psi_1 + i\psi_2$ as well as χ_3 and ψ_3 were computed by the FTBPF with the parameter value λ = 0.0015 and the HWT with the parameter values λ =0.005, σ = 0.005 (Fig. 2).

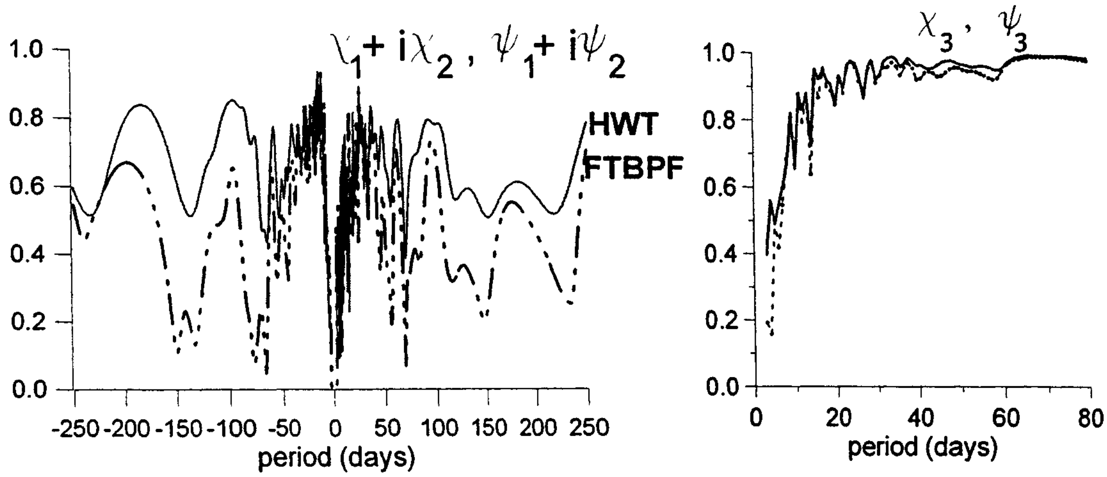

Fig. 2. The coherence between the atmospheric χ_1, χ_2, χ_3 and geodetic ψ_1, ψ_2, ψ_3 excitation functions computed by the FTBPF (λ = 0.0015) (dotted line) and the HWT (λ = 0.005, σ = 0.005) (solid line).

It can be noticed that the coherence between equatorial components of the atmospheric and geodetic excitation function is usually greater for the HWT than for the FTBPF and of the order of 0.6-0.8 for 182 and ~100-day retrograde oscillations, 0.9 for ~10-day retrograde oscillation and ~25-day prograde oscillation. The coherence between the axial components of the atmospheric and geodetic excitation functions is very high for oscillations with periods greater than ~20 days. The coherence functions computed by the two methods vary similarly with a period change for the equatorial and axial components of the excitation functions. The time variable FTBPF and the HWT time-frequency coherences between the equatorial components of the atmospheric and geodetic excitation functions computed by Kosek and Popiński (1999) show also agreement in time variations for the two methods.

CONCLUSIONS

The HWT and FTBPF enable computation of time-frequency and time variable spectra of LOD data with a possibility of changing frequency resolution, however, the FTBPF enables improving time resolution too by increasing the λ parameter value. The coherences between the atmospheric and geodetic excitation functions computed by the FTBPF and HWT are very similar, though the FTBPF coherence between equatorial components of the atmospheric and geodetic excitation functions has usually smaller values than the HWT coherence. The coherence between axial components of the atmospheric and geodetic excitation functions drops for oscillations with periods less than ~20-days.

Acknowledgements. This paper was supported by the grant of the Polish Committee of Scientific Research No 52/T12/97/13 under the leadership of Prof. B. Kołaczek.

REFERENCES

Barnes R.T.H., Hide R., White A.A., and Wilson C.A. 1983, Atmospheric Angular Momentum Fluctuations, length-of-day changes and polar motion, *Proc. R. Soc. London, A387*, 31-73.

Chui C.K. 1992, An Introduction to Wavelets, *Wavelet Analysis and its Application Vol. 1*, Academic Press, Boston-San Diego.

IERS 1998, Annual Report, Observatoire de Paris, France,

Kosek W. 1995, Time Variable Band Pass Filter Spectra of Real and Complex-Valued Polar Motion Series, *Artificial Satellites, Planetary Geodesy, No 24, Vol. 30, No 1*, 27-43.

Kosek W., McCarthy D.D., Luzum B. 1998, Possible Improvement of Earth Orientation Forecast Using Autocovariance Prediction Procedures, *Journal of Geodesy 72*, 189-199.

Kosek W., Popiński W. 1999, Comparison of the spectro-temporal analysis methods on polar motion and its atmospheric excitation. *Artificial Satellites, Journal of Planetary Geodesy, Vol. 34, No 2*, 65-75.

McCarthy D.D. (ed.) 1996, IERS Conventions (1996), *IERS Technical Note 21*, Paris, France.

Newland D.E. 1998, Time-Frequency and Time-Scale Signal Analysis by Harmonic Wavelets, in *Signal Analysis and Prediction*, A. Prohazka, J. Uhlir, P.J. Rayner, N.G. Kingsbury (eds), Birkhauser, Boston.

Otnes R.K., Enochson L. 1972, *Digital Time Series Analysis*, John Wiley and Sons Publishing Company, New York.

Popiński W., Kosek W. 1994, Wavelet Transform and Its Application for Short Period Earth Rotation Analysis, *Artificial Satellites, Vol. 29, No 2*, 75-83.

Popiński W., Kosek W. 1995a, Discrete Fourier and Wavelet Transforms in Analysis of Earth Rotation Parameters, in Proc. *Journees 1995 - Earth Rotation, Reference Systems in Geodynamics and Solar System*, 18-20 September, Warsaw, Poland, 121-124.

Popiński W., Kosek W. 1995b, The Fourier Transform Band Pass Filter and its Application to Polar Motion Analysis, *Artificial Satellites, Vol. 30, No 1*, 9-25.

Salstein, D.A., D.M. Kann, A.J. Miller, R.D. Rosen 1993, The Sub-bureau for Atmospheric Angular Momentum of the IERS: A Meteorological Data Center with Geodetic Applications., Bull. Amer. Meteor. Soc., 74, 67-80.

Wilson C.R. and Haubrich R.A. 1976, Meteorological Excitation of the Earth's Wobble, *Geophys. J. R. Astron. Soc. 46*, 707-743.