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MOVING LEAST SQUARES SPECTRA SCRUTINIZE CHRONOMICS IN AND AROUND US

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Abstract

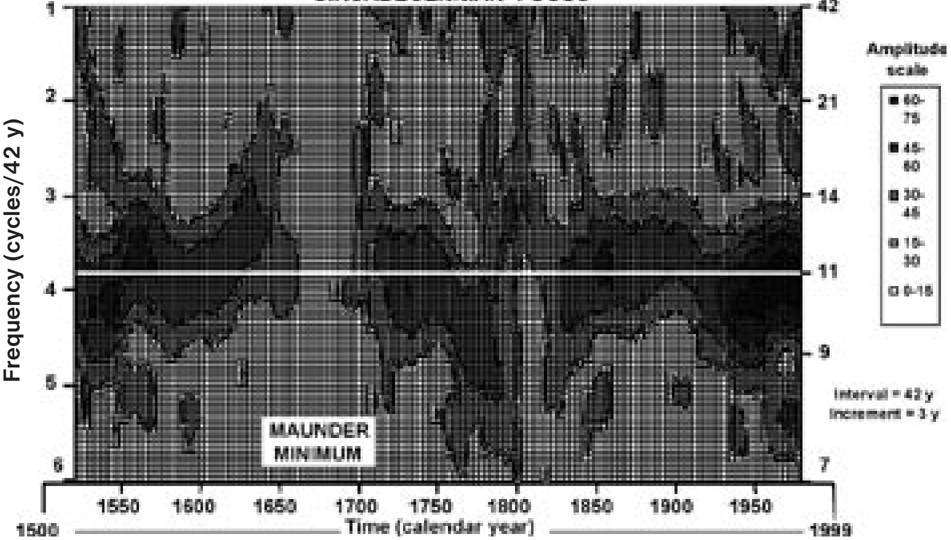
As an extension of the chronobiological serial section, gliding spectra illustrate the changing time structure (chronome) of physiological, physical and/or other variables in a given frequency range. For this purpose, least squares spectra are computed over a specified interval (much shorter than the observation span) that is progressively displaced by a given increment throughout the entire record. Results can be displayed either as 3D charts or as surface charts, displaying the estimated amplitudes, percentage rhythms or ordering P-values at each trial period for each interval. The procedure is illustrated for the record of Wolf numbers as a gauge of solar activity and for the number of marriages and divorces in Japan during the past century. Major components in these time series show deviations in period length and relative prominence over time. Particularly in the case of non-stationary time series, gliding spectra offer themselves as useful tools to examine changes in time structure beyond a specific spectral component.

Key words

Least squares spectra method, Chronobiology, Analysis of time structure

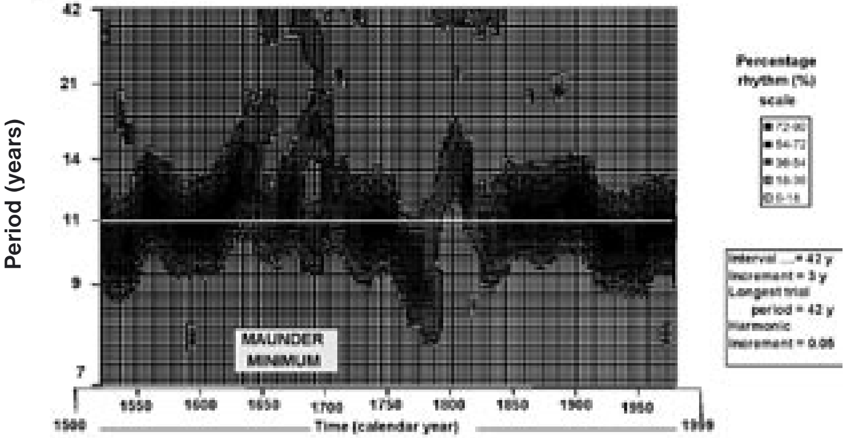
INTRODUCTION

Moving least squares spectra represent an extension of the chronobiological serial section (*1, 2*) and of serial sections on a serial section (*3*) to view changes as a function of time in the characteristics (MESOR, rhythm-adjusted mean value; amplitude, a measure of half the extent of predictable change within a cycle; and acrophase, a measure of the timing of overall high values recurring in each cycle) of an anticipated spectral component. The technique is useful to assess the consistency of the time structure of a given variable over time and to assess any changes when such occur, as in the case of variations in acrophase and/or frequency following a transmeridian flight (*4*) or in the case of variance transpositions in vascular time structures postnatally during child development (*5*).



SOLAR ACTIVITY (WOLF NUMBERS) OVERVIEW: 500 YEARS
CIRCADECENNIAN FOCUS

CIRCADECADAL FOCUS by MOVING RELATIVE "POWER" SPECTRUM
(percentage rhythm) of WOLF's SUNSPOT NUMBERS OVER 500 YEARS

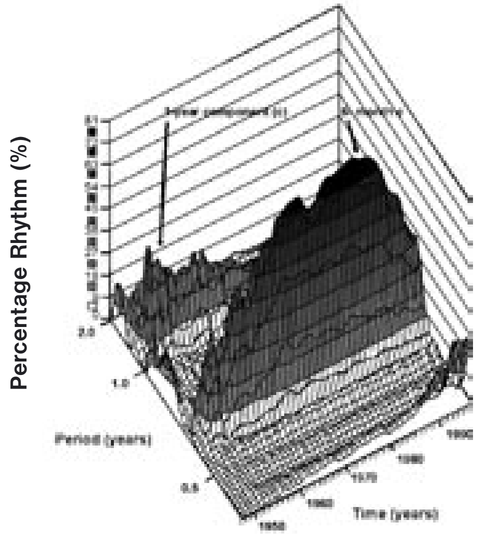


Note apart from continuity during Maunder minimum (at variance with hiatus suggested elsewhere by very low amplitudes) another span before 1800 of a circadecadal "relative power minimum".

Fig. 1

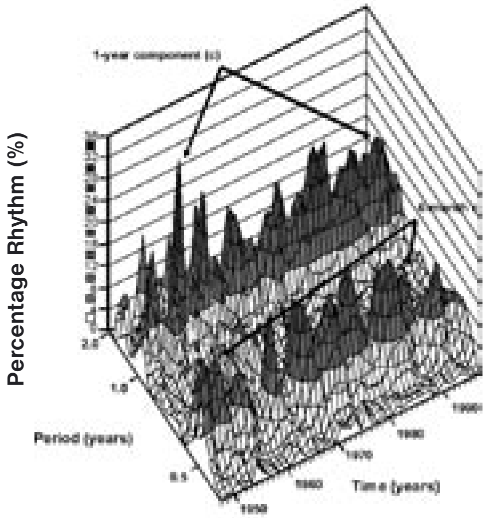
Gliding spectra of yearly Wolf numbers focusing on the about 11–year cycle of solar activity. Amplitudes (top) clearly indicate decrease in solar activity during Maunder minimum, whereas percentage rhythm values (bottom) show the persistence of the about 11–year cycle throughout the entire record. Both graphs illustrate the wobbliness of the solar activity cycle, the average period varying in a wide range covering several years.

CIRCASEMIANNUAL (VERSUS CIRCANNUAL) PROMINENCE*
in MARRIAGE CHRONOME (TOKYO, 1946 - 1999)



Interval = 2 years; increment of interval-displacement = 1 year;
longest trial period = 2 years; increment of trial frequency = 0.1 harmonic;
N of monthly values = 642.

CIRCASEMIANNUAL & CIRCANNUAL ASPECTS*
of DIVORCE CHRONOME (TOKYO, 1946 - 1999)



Interval = 2 years; increment of interval-displacement = 1 year;
longest trial period = 2 years; increment of trial frequency = 0.1 harmonic;
N of monthly values = 642.

Fig.2

3D spectra show an increase in the prominence of a half-yearly versus yearly pattern which is observed for marriages (left) but not for divorces (right) recorded during the past century in Japan.

MATERIALS AND METHODS

A C++ program described earlier (*2*) was applied to several time series to illustrate the merits of the procedure, applicable to equidistant or non-equidistant data, time-coded in arbitrary units or, whenever possible, as century, year, month, day, hour, and minute of each value. The program is interactive and prompts the user to enter selections, such as the length of the interval to be used for the computation of the least squares spectrum, and the increment by which this interval should be moved throughout the time series. The program also offers many other choices between the computation of a least squares spectrum, wherein trial periods are in harmonic relation in a specified frequency range, and that of a chronobiological window (*1*), wherein trial periods are changed by a specific amount within a narrow frequency range. To examine a narrow frequency range, as for instance to check on free-running (*6, 7*), the sequence of the trial periods can be chosen in arithmetical progression, i.e., linearly in period.

RESULTS

The output of the program consists of a set of files, constructed as matrices (tabulations) in which each column presents values of outcomes corresponding to a given trial period. Different endpoints (e.g., amplitude, percentage rhythm, P-value) are provided in different computational outcome files. All of the matrices show the prominence of each of the frequency components as it changes as a function of time. Of particular interest is the matrix of amplitudes, which shows the absolute prominence of oscillations, and the matrix of percentage rhythm values (equivalent to the R^2), which permits the evaluation of the distribution of the overall variance among the different frequencies. Matrices can be plotted as a contour map (surface chart) in commercially available software packages (such as Microsoft Excel) (2).

The program is illustrated in *Fig. 1* for solar activity, gauged by yearly Wolf numbers available for the span 1700–1999. Sidebands around the wobbly about 11-year cycle in solar activity (not shown) suggest modulations in amplitude and/or phase by unstable components with a period varying around 100 years. Amplitudes of the about 11-year cycle (*Fig. 1*, top) clearly indicate that a decrease in solar activity occurred during the Maunder minimum, whereas the values of percentage rhythm (*Fig. 1*, bottom) show the persistence of the about 11-year cycle throughout the entire record. Both graphs in *Fig. 1* illustrate the wobbliness of the solar activity cycle, the average period varying in a wide range covering several years.

Major changes in the chronomes of blood pressure and heart rate during the first 40 days after birth have been visualized with gliding spectra (*5*). They pictured the previously demonstrated variance transposition from prominent circaseptans in early extrauterine life to a predominantly circadian structure later in life (*8–10*).

Fig. 2 shows the application of gliding spectra to the number of marriages and divorces in Japan during the past century. An increase in the prominence of a half-yearly versus yearly pattern is observed for marriages but not for divorces (*11*).

DISCUSSION

The time structure of Wolf numbers, individual physiological time series, and social events such as marriages and divorces, all differ from exact periodicities. To analyse such non-stationary data, the moving spectra matrices and contour maps offer themselves as useful tools, beyond the chronobiological serial section, examining changes beyond a specific spectral component.

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Souhrn

Jako další rozvinutí chronobiologických časových řad klouzavá spektra ukazují na měnící se časové struktury (chronomy) fyziologických, fyzikálních nebo jiných proměnných v určitých frekvenčních pásmech. Z tohoto důvodu jsou počítána spektra nejmenších čtverců v daném časovém intervalu (mnohem menším než je doba sledování), kde interval je postupně posunut o určitý přírůstek, až se dosáhne konce celkového záznamu. Výsledky mohou být znázorněny na trojrozměrném diagramu znázorňujícím odhady amplitud, procento rytmu nebo příslušné hodnoty pravděpodobnosti při každé experimentální fázi v každém intervalu. Postup znázorňuje záznam Wolfových čísel jako indikátorů solární aktivity a frekvence svateb a rozvodů v Japonsku v minulém století. Hlavní komponenty v těchto časových řadách ukazují odchylky v trvání periody a relativní prominenci v průběhu času. Zvláště v případě nestacionárních časových řad představují klouzavá spektra užitečný nástroj ke sledování změn v časové struktuře nad specifickou spektrální složku.

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