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## Terrestrial and solar magnetism' influence to diphtheria pandemics

**Abstract.** The number of physicochemical factors of the environment is extremely high. The geophysical components of the environment are under the influence of cosmic forces. The sun, the moon, the planets and the stars are connected with the Earth by invisible bonds. Gravitation, radiation, electromagnetic fields and corpuscular ceilings of the Sun and stars are far from a complete list of the cosmic forces acting on the Earth. Changes in the activity of the Sun are reflected in the biosphere directly through photosynthesis of plants, and indirectly through changes in climatic conditions on the Earth, which affects various biological processes. One of the first scientists, who paid attention to the dependence of pandemics with solar cycles, was Alexander Chizhevsky.

In this study, we perform a meta-analysis of statistical data on diphtheria, based on the data published by Chizhevsky in the 20th century. We here add for the association of terrestrial and solar magnetism with these infectious diseases that were common in the past, using nonlinear analysis, cosinor-analysis and cross-wavelet coherence. We showed the geographic differences hidden in Chizhevsky's data on diphtheria. Wavelets of Wolf numbers and of the antipodal geomagnetic index show maxima corresponding to the anticipated ~11.7-year cycle, also seen from the spectra plotted vertically next to the color key. The numbers indicate the period length (in years) corresponding to local maxima in amplitudes; but the color code matters most. The wavelet also reveals the presence of an about 22.1-year component differing from the smaller about 19.7-year peaklet observed for Wolf numbers. Both these peaks are less prominent than the about 29.5-year peak found for diphtheria.

**Key words:** Chizhevsky, diphtheria, helio- and geomagnetism, cycles in communicable disease incidence

The number of physicochemical factors of the environment is extremely high. The geophysical components of the environment are under the influence of cosmic forces. The sun, the moon, the planets and the stars are connected with the Earth by invisible bonds. Gravitation, radiation, electromagnetic fields and corpuscular ceilings of the Sun and stars are far from a complete list of the cosmic forces acting on the Earth. Changes in the activity of the Sun are reflected in the biosphere directly through photosynthesis of plants, and indirectly through changes in climatic conditions on the Earth, which affects various biological processes. One of the first scientists, who paid attention to the dependence of pandemics with solar cycles, was Alexander Chizhevsky.

In this study, we made a meta-analysis of statistical data on diphtheria, based on the data published by Chizhevsky in the 20th century dating back to the span from 1860 to 1910 [1], we here add for the association of terrestrial and solar magnetism with these infectious diseases that were common in the past, using nonlinear analysis, cosinor-analysis and cross-wavelet coherence [2-6]. We showed the geographic

differences hidden in Chizhevsky's data on diphtheria. Diphtheria is a bacterial infection caused by *Corynebacterium diphtheria*, transmitted from person to person through close physical and respiratory contact. It can cause infection of the nasopharynx, which may lead to breathing difficulties and death. WHO reports about 4530 cases of death for 2015 [7].

For the span from 1860 to 1912, Shostakovich in Irkutsk resolved two  $\tau$ s of 2.77 and 11.33 years for data from Denmark [1]. Our meta-analyses were on yearly data on the incidence of diphtheria in Denmark, Sweden, Switzerland, England and Wales, and Romania, that all ended in 1910 but started at different times for the different countries, namely 1860 (England and Wales, and Denmark,  $T=51$  years), 1861 (Sweden,  $T=50$  years), 1876 (Switzerland,  $T=35$  years), and 1886 (Romania,  $T=25$  years). The database is actually larger, also including data from Prussia, Scotland, Belgium, Holland, Ireland, Austria, Italy, and France, for which, however, a nonlinear validation of linear results failed in our hands.

First, the data from all countries were plotted in chronograms, with superposed curves for the differ-

ent countries to check on similar trends as a function of time, and also separately for the 5 countries of interest wherein a nonlinear validation of a  $\tau$  was possible. Polynomial fits examined the extent to which such should be included in analyses aimed at assessing any periodicities. By visual inspection, whereas no trend was apparently needed for data from Romania and Denmark, a linear trend seemed desirable and was included for data from Switzerland and Sweden, and a third-order polynomial for data from England and Wales.

Least squares spectra were computed using a fundamental  $\tau$  of 51 years and a 0.2 harmonic increment. Average amplitude (phase-unweighted) spectra were computed, including results from all countries as well as from the 5 countries of interest here. As expected, amplitudes tended to be much larger at low frequencies, likely related to trends present for most time series. Differences are observed by the naked eye in the spectral structure of statistics from the 5 countries, with spectral peaks occurring at different frequencies in different geographic locations.

Overall, a few peaklets are found that correspond approximately to cycles with  $\tau$ s of about 17, 12, 10.2, 6, and 3.5 years. Focus was first placed on putative components with  $\tau$ s of about 17 and 12 years. Nonlinear analyses were performed, using a single component model with a trial  $\tau$  of either 12.0 or 17.2 years. Analyses were carried out as such and with the addition of a linear trend or a third-order polynomial. At a trial  $\tau$  of 12 years, in Switzerland the  $\tau$  converges toward 10.63, 12.01 or 13.03 years depending on whether there is no trend, a linear trend or a third-order polynomial. The conservative CI for the amplitude does not overlap zero only in the case of the model including a linear trend. In this case, the  $\tau$  is estimated as 12.01 (CI: 9.80, 14.21) years, with an amplitude of 8.52 (CI: 0.22, 16.81) (table 1). There is a large discrepancy in the estimate of the  $\tau$  for this country depending on whether a linear trend is included in the model or not. In England and Wales, the  $\tau$  converges to 12.61, 12.20 or 11.07 years, respectively, but the CI of the amplitude invariably covers zero. In Romania, the  $\tau$  converges to 16.73, 16.96, or 16.24 years, respectively, but in the latter case (including a third-order polynomial), the model does not fit and a CI cannot be obtained for the  $\tau$ . Without a trend, the  $\tau$  is estimated as 16.73 (CI: 12.66, 20.80) years and the amplitude as 9.65 (CI: 2.86, 16.45). In Denmark, the  $\tau$  converges to 12.03, 11.96, or 13.47 years, respectively, the CI of the amplitude invariably not covering the pole. As no trend seemed to be needed, the  $\tau$  can be estimated as 12.03 (CI: 10.72,

13.33) years with an amplitude of 33.89 (CI: 7.09, 60.69). In Sweden, the  $\tau$  converges to 12.58, 12.76, or 17.44 years, a CI of the amplitude not covering zero only when a third-order polynomial is included, in which case the  $\tau$  estimate converges to a longer  $\tau$  of 17.44 years.

At a trial  $\tau$  of 17.2 years, in Switzerland the  $\tau$  converges toward 16.99, 12.01 or 12.70 years depending on whether there is no trend, a linear trend or a third-order polynomial, the CI for the amplitude not overlapping zero in the case of the model including a linear trend or no trend. Note the large discrepancy in  $\tau$  estimate depending on whether a linear trend is included or not in the model. Furthermore, when a linear trend is included in the model, the same results are obtained whether the trial  $\tau$  is 12.0 or 17.2 years. In England and Wales, the  $\tau$  converges to 17.46, 17.58 or 16.08 years, respectively, the CI of the amplitude covering zero in the latter case. Relying on a linear trend rather than on a third-order polynomial, the  $\tau$  is estimated as 17.58 (CI: 14.28, 20.88) years, with an amplitude of 4.72 (CI: 0.18, 9.26). In Romania, the  $\tau$  converges to 16.73, 16.96, or 16.24 years, respectively, but in the latter case (including a third-order polynomial), the model does not fit and a CI cannot be obtained for the  $\tau$ . Note that these results are the same as those obtained with a trial  $\tau$  of 12.0 years. As no trend seemed to be present, the  $\tau$  can be estimated as 16.73 (12.66, 20.79) years and the amplitude as 9.65 (CI: 2.86, 16.45). In Sweden, the  $\tau$  converges to 17.71, 18.02, or 17.44 years, the CI of the amplitude invariably not covering zero. As a linear trend appeared to be present, the  $\tau$  can be estimated as 18.02 (CI: 15.23, 20.81) years and the amplitude as 19.69 (CI: 5.67, 33.70). In Denmark, the  $\tau$  converges to 33.04, 36.98, or 24.88 years, respectively, the CI of the amplitude invariably not covering the pole. Note that these  $\tau$  estimates are much longer than the trial  $\tau$  of 17.2 years, two of which correspond to a Brückner-Egeson-Lockyer (BEL) paratridecadal defined only by its CI approaching (not necessarily covering) the 30-40-year range.

William J.S. Lockyer [8-10] associated the paratridecadal with the  $\tau$  he found to characterize changes of the length of the variable circadecadal Horrebow-Schwabe cycle in relative sunspot numbers, as confirmed by Liznar [11], a topic also of interest in 1903 to William Lockyer's father Sir J. Norman Lockyer, the codiscoverer of helium and founder of the journal *Nature* [10]. We now recognize that this cycle's  $\tau$  length is highly variable, on the average, longer than (i.e., beyond = trans) 30 years, hence originally dubbed transtridecadal.

The BEL cycle (acronym taken from the initials of Brückner, Egeson and Lockyer) was defined as a cycle with the CI of its period ( $\tau$ ) overlapping (this definition was liberalized to the CI approaching) the

range of 30 to 40 years. This was prompted by point estimates of  $\tau$ , close to, but outside the 30-40-year range of variables closely related to those with  $\tau$  inside that range.

**Table 1** – Geomagnetic/geographic differences among cycles with periods in the range of 5 – 32 years, characterizing the incidence of diphtheria

Site	Span	Period (y) (95% CI)	Amplitude (95 % CI)	A (% of MESOR)	P-value
Kherson province	1874-1908	19.38 (14.53, 24.22)	31.93 (9.71, 54.15)	46	<0.005
Kherson county	1874-1908	16.996 (13.83, 20.16)	12.54 (3.42, 21.67)	36	<0.001
Elizavetgrad county	1874-1908	20.53 (17.23, 25.05)	27.74 (9.92, 45.56)	65	<0.005
Denmark	1860-1910	31.78 (25.80, 37.76)	43.91 (19.35, 68.46)	66	<0.001
		11.99 (10.89, 13.09)	35.77 (12.18, 59.36)	54	<0.001
Prussia	1875-1910	9.10 (6.63, 11.58)	24.27 (22.14, 70.68)	23	<0.05
Switzerland	1876-1910	16.98 (12.76, 21.2)	13.04 (0.04, 26.04)	36	<0.001
		12.01 (9.80, 14.21)	8.52 (0.22, 16.81)	23	<0.001
Scotland	1860-1910	26.33 (18.17, 34.30)	11.96 (0.38, 24.30)	29	<0.001
		12.75 (10.07, 15.42)	8.6 (0.00, 21.73)	21	<0.05
		9.89 (8.56, 11.22)	9.94 (0.00, 23.03)	41	<0.05
Belgium	1870-1910	21.49 (10.02, 32.96)	12.69 (9.02, 34.41)	23	<0.001
		14.02 (9.27, 18.78)	12.71 (9.08, 34.50)	23	<0.001
Holland	1875-1910	14.02 (9.42, 18.61)	6.82 (0.00, 17.6)	27	<0.05
		9.35 (7.64, 11.07)	8.23 (0.00, 18.48)	33	<0.05
England and Wales	1860-1910	29.37 (23.15, 35.59)	8.89 (4.06, 13.73)	29	<0.001
		17.46 (14.66, 20.26)	7.04 (1.32, 12.76)	23	0.001
		12.58 (10.53, 14.64)	5.10 (0.00, 11.37)	17	<0.05
Ireland	1864-1910	24.16 (10.45, 37.87)	3.21 (2.92, 9.34)	14	<0.05
		17.27 (7.67, 26.86)	2.29 (4.04, 8.63)	10	<0.05
		12.40 (9.26, 15.53)	3.62 (2.5, 9.73)	15	<0.05
		7.84 (6.54, 9.15)	3.42 (2.76, 9.59)	14	<0.05
Romania	1886-1910	16.73 (12.66, 20.80)	9.65 (2.86, 16.45)	49	<0.001
Austria	1880-1910	16.09 (7.55, 24.64)	23.66 (17.58, 64.9)	25	<0.001
Italy	1887-1910	12.51 (2.66, 22.36)	9.57 (14.64, 33.77)	28	<0.001
France	1889-1910	11.26 (7.056, 15.52)	13.528 (0.00, 30.624)	51	<0.05
Sweden	1861-1910	17.71 (15.45, 19.98)	22.00 (8.72, 35.28)	42	<0.001
		12.58 (10.16, 14.99)	11.89 (0.00, 28.14)	23	<0.05

In turning to the comment that Shostakovich found components with periods of 2.77 and 11.33 years in Denmark, additional nonlinear analyses were performed to examine whether these results could be validated. First, a single component with a trial period of 2.8 years was used, but could not be detected with statistical significance. In view of the large spectral peak corresponding to a period of

about 12 years, this component was added to the model. This 2-component model resembles that of Shostakovich, but only the 12-year component could be demonstrated, the CI of the amplitude only slightly overlapping zero when the 2.8-year component is included in the model. Examination of the least squares spectrum, and in keeping with the nonlinear results reported above, statistics in Denmark

are characterized by two large spectral peaks, corresponding to  $\tau$ s of about 32 and 12 years with two other smaller peaks also present with  $\tau$ s of about 6.7 and 3.5 years. Using this 4-component model, non-linear results can only validate the first two components. Replacing the trial  $\tau$  of 3.5 years with one of 2.9 years, in keeping with the report by Shostakovich, also validates only the first two components. A three-component model, excluding the 3.5- or 2.9-year component, also cannot validate the 6.7-year cycle. But a two-component model with trial  $\tau$ s of

32 and 12 years fits.  $\tau$ s are estimated as 31.78 (CI: 25.80, 37.76) and 11.99 (CI: 10.89, 13.09) years with respective amplitudes of 43.91 (CI: 19.35, 68.46) and 35.77 (CI: 12.18, 59.36). Figure 1 shows that the results are roughly in agreement for England and Wales, Romania, Sweden and one country in Russia with about 16-18-year cycles, but in Switzerland and Denmark, dominant components have  $\tau$ s around 12 years; Denmark also has a BEL, and Russia has  $\tau$ s with a CI nearing or covering 21 years.

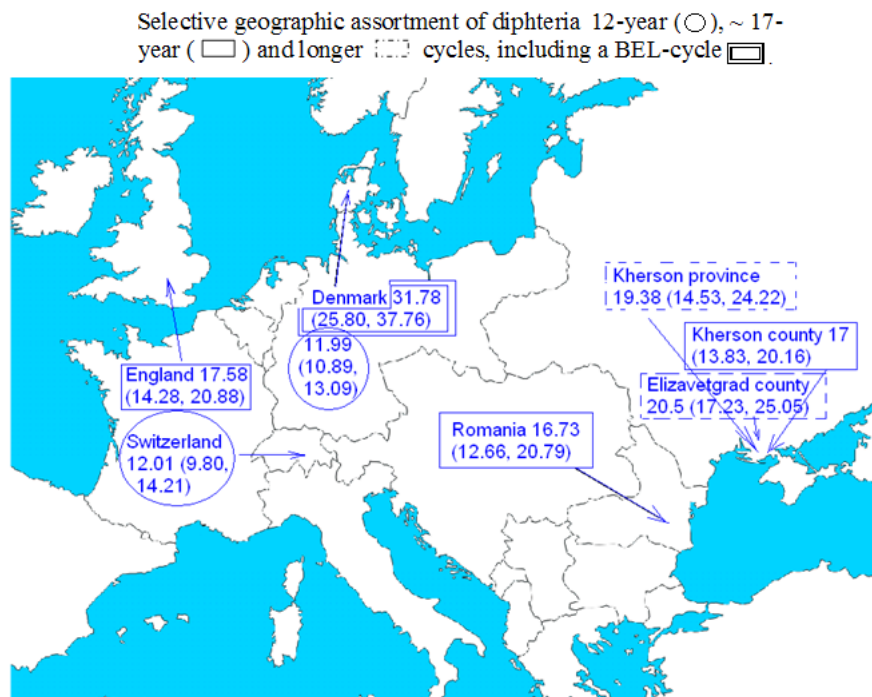


Figure 1 – Geographic map of infra-annual cycles characterizing the incidence of diphtheria

Data on diphtheria were also analyzed in some regions of what was formerly south Russia, now Ukraine: Herson county (uezd), Elizabet county and all of Herson province (guverny).

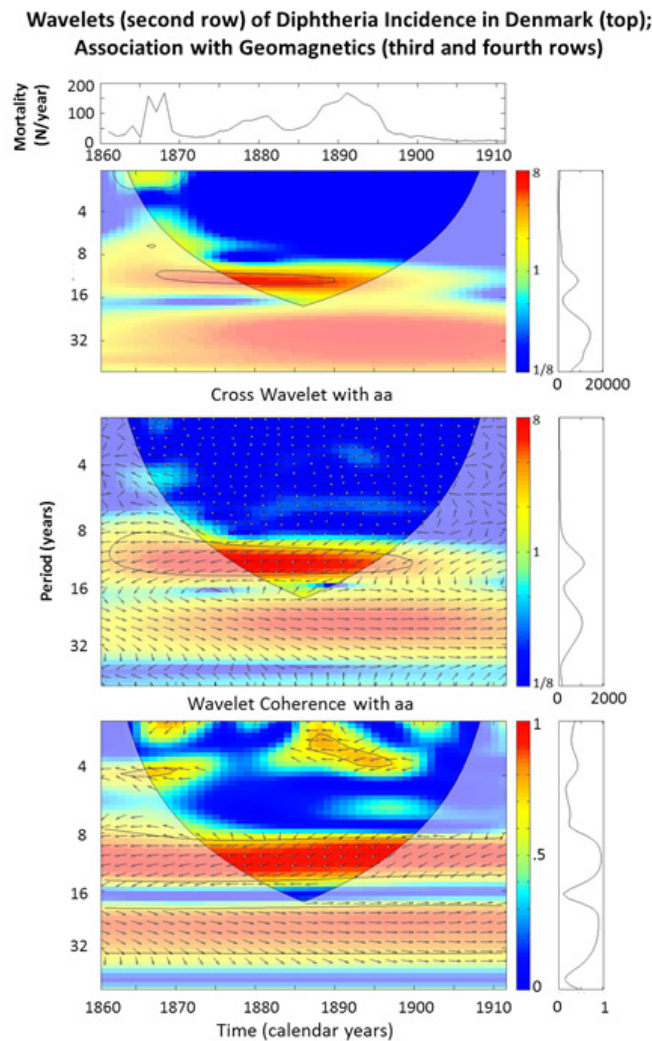
Figure 1 shows the dynamics of diphtheria in Russia (using a square root transformation of data): in Elizabet county the  $\tau$  was 20.5 (17.2, 25) years with an amplitude of 27.74 (9.9, 45.56); in Herson county it was 17 (13.83, 20.16) years with an amplitude of 12.54 (3.37, 21.71), and in the larger Herson province, that included 7 other counties with Herson and Elizabet counties, nonlinear analysis shows a period of 19.38 (14.53, 24.22) years with an amplitude of 31.93 (9.71, 54.15).

We here show the presence of several cycles that may correspond to the Horrebow-Schwabe, the

Hale, and the Brückner-Egeson-Lockyer cycles, among others. Such correspondence can only prompt a subtraction-addition approach. The use of special computer programs allows us to more accurately estimate the periods. A pardecadal 8.25-12.93-year cycle was found in Denmark, Belgium, Switzerland, Scotland, England (and Wales) and Ireland, whereas in Austria, Italy, Romania and Sweden, the period length of the most prominent cycle was between 15 and 18.8 years (Table 1). In the dynamics of diphtheria in the Kherson province (then South Russia, now Ukraine), statistically significant periodicities include a point estimate of 17 years, with others of 19.4 and 21 years, but with very wide overlapping CIs so that the periods cannot be separated. In Russia, only relapsing fever in Moscow had a prominent

decadal period, Table 1 (bottom), a detail qualifying even a genius like Chizhevsky. If not an «echo» only to the sun, the biosphere and the noosphere it created are resonators to both the sun and the earth, among others, and the various environmental influences compete (wrangle) with one or the other dominating in different geographic regions at the same time. Figure 2 (top) shows a wavelet of the incidence pattern

of diphtheria in Denmark from 1860–1910. An about 12.4-year component is seen to characterize the incidence pattern; it is within the cone of influence. Another component with a period of about 29.5 years is outside this cone. Both components are validated and are within the CIs (95% confidence intervals) of the nonlinearly extended cosinor, applied to the same time series on diphtheria.



**Figure 2** – Wavelet analyses of incidence pattern of two infectious diseases (pooled) centuries ago (top row), of Wolf sunspot numbers (middle), and of the antipodal geomagnetic index aa (bottom), with peaks indicated by color (key), and by numbers at the maxima in the spectrum (right, next to the color key) show a putative reflection of past and/or present solar variability

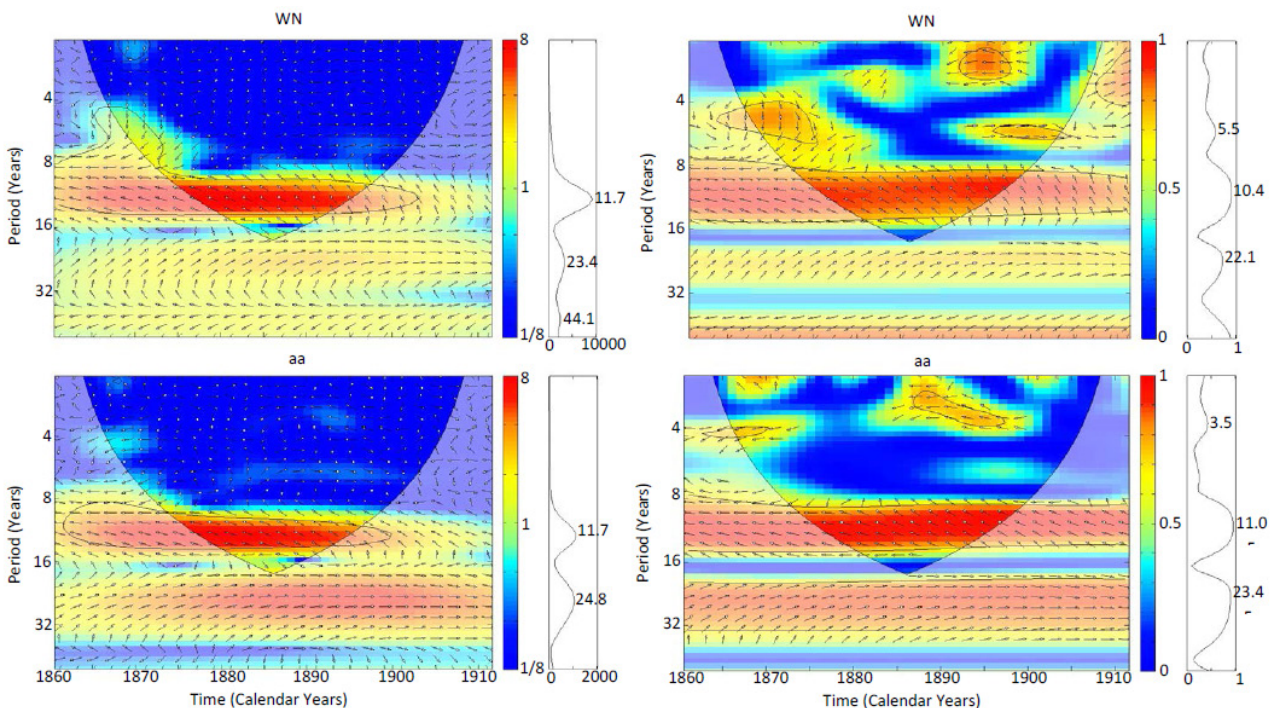
Wavelets of Wolf numbers, WN (Figure 2, middle), and of the antipodal geomagnetic index aa (Figure 2, bottom) show maxima corresponding to the anticipated ~11.7-year cycle, also seen from the spectra plotted vertically next to the color key. The numbers

indicate the period length (in years) corresponding to local maxima in amplitudes; but the color code matters most. The wavelet of aa also reveals the presence of an about 22.1-year component differing from the smaller about 19.7-year peaklet observed for WN.

Both these peaks are less prominent than the about 29.5-year peak found for diphtheria.

Figure 3 shows cross-wavelet transforms (left) and coherence displays (right) of WN (top) and aa (bottom) with diphtheria. The 11.7-year period within the cone of influence stands out in association with both WN and aa in the cross-wavelets. An added large peak at 24.2 years is seen in association with aa. Peaklets are seen at ~23 and ~44 years in association with WN. Strong coherences around 10.4 (WN) or 11.0 (aa) years inside the cone of influence and additional strong coherences outside this cone around 23.4 (aa) or less intensely around 22.1 (WN) years are interesting. Added coherences around 5.5 years and at still shorter pperods in association with WN are intermittently statistically significant (as seen from black contours). Again, there is a difference in spectral location between WN and aa, the overall peak occurring around 3.5 years for aa.

Among para-annual components, solar wind speed, a measure of interplanetary magnetism, and aa share some frequencies but differ at others [12]. Here we find that, in the decadal range, both WN and aa, gauging solar and terrestrial magnetism, respectively, shared coherence (within the cone of influence) with the main cycle characterizing communicable diseases, such as diphtheria, in the past when they were pandemic. Just as helio-, inter- planetary or geomagnetism can influence sudden cardiac death [12, 13], they also influenced communicable diseases, probably via the host, whose steroidal defense shows a proven decadal cycle [12] and by the invading microorganism, whose mutations can also undergo a similar cycle mirroring that of sunspots [12]. Cycles in the sun's and the earth's magnetism are features of both communicable and noncommunicable disease etiology and, in both cases, are geo- graphically, selectively assorted, shown elsewhere [13, 14].



**Figure 3** – Cross-wavelet transforms show a strong association of the incidence of two infectious diseases (pooled) with WN and aa at a period,  $t$ , of 11.7 years within the cone of influence. Coherence (right) is also found within the cone of influence at 10.4 and 11.0 years. These  $t$ s are also near those validated for the incidence of diphtheria by the extended nonlinear cosinor (not shown) that suggests the statistical significance of differences among the two aspects of solar and earth magnetism's association with rampant pandemics, some within the cone of influence.

## References

1. Chizhevsky AL. The Terrestrial Echo of Solar Storms, 2nd ed. Moscow: Mysl, 1976, pp. 367.
2. Marquardt DW. An algorithm for least-squares estimation of nonlinear parameters. *J Soc Indust Appl Math* 11: 431-441, 1963.
3. Halberg F. Chronobiology: methodological problems. *Acta med rom* 18: 399-440, 1980
4. Cornélissen G, Halberg F. Chronomedicine. In: Armitage P, Colton T (Eds.) *Encyclopedia of Biostatistics*, 2nd ed. Chichester, UK: John Wiley & Sons Ltd; 2005. p. 796-812.
5. Refinetti R, Cornélissen G, Halberg F. Procedures for numerical analysis of circadian rhythms. *Biological Rhythm Research* 38 (4): 275-325, 2007.
6. Grinsted A, Moore JC, Jevrejeva S. Application of the cross wavelet transform and wavelet coherence to geo- physical time series. *Nonlinear Processes in Geophysics* 2004; 11: 561–566
7. WHO report: Immunization, Vaccines and Biologicals. Diphtheria [http://www.who.int/immunization/monitoring\\_surveillance/burden/diphtheria/en/](http://www.who.int/immunization/monitoring_surveillance/burden/diphtheria/en/) – Accessed December 16, 2016
8. Lockyer WJS. The solar activity 1833-1900. *Proc Roy Soc Lond* 1901; 68: 285-300.
9. Lockyer WJS. Die Sonnentätigkeit 1833-1900. *Meteorologische Zeitschrift* 1902; 19: 59-71.
10. Lockyer N. Simultaneous solar and terrestrial changes. *Science* 1901; 18: 611-623.
11. Liznar J. Über die 33-jährige Periode der Sonnenflecken, *Meteorologische Zeitschrift* 1902; 19: 237-238.
12. Halberg F, Cornélissen G, Sothorn RB, Czaplicki J, Schwartzkopff O. Thirty-five-year climatic cycle in heliogeophysics, psychophysiology, military politics, and economics. *Izvestiya, Atmospheric and Oceanic Physics* 2010; 46 (7): 844–864.
13. Gumarova L., Cornélissen G., Hillman D., Halberg F. Geographically selective assortment of cycles in pandemics: Meta-analysis of data collected by Chizhevsky. // *Epidemiology and Infection*, Vol. 141, Issue 10, 2013, p. 2173-2184.
14. Gumarova L., Cornélissen G., Dimitrov B.D., Halberg F. Transyears competing with the seasons in tropical malaria incidence // in book: *Current Topics in Malaria*. – InTech, 2016, pp 39-52. – ISBN 978-953-51-2790-1, Print ISBN 978-953-51-2789-5, 504 p.