

The Relationship between Suicide Incidents in Slovakia and the Czech Republic and Heliophysical Parameters: Empirical Results

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Abstract

Suicide has been attributed to social and economic factors but changes in solar radiation and geomagnetic activities may contribute to the frequency and the seasonal pattern of suicides. We studied the relationship between suicide episodes in Slovakia and the Czech Republic and parameters of solar, heliospheric and geomagnetic activity during the period of 1982 to 2011. Along with checking the linear correlation between the suicide event number and the physical parameters of outer space on yearly basis, the contribution of the harmonic component with periodicity near that of the heliophysical characteristics was examined and optimum frequency of such contribution was estimated used detrended time series. The results show a weak effect of solar and geomagnetic activity variations on the suicide incidents in the given data set. Higher statistics and better temporal resolution of the data is needed to obtain more conclusive results.

Keywords: Suicide incidents; Cosmic ray intensity; Sunspot number; Ap-index; 10.7 cm radio flux

Introduction

The possible impact of solar, cosmic rays and geomagnetic activity has become the subject of many research studies. Several studies have been made to investigate space weather hazards and their impact on human cardio-health state parameters. It was shown that geomagnetic activity (GMA) and cosmic ray intensity (CRI) variations could be considered as one of the indicators of space weather, which play a role in regulating external factors in human homeostasis, particularly, cardio - vascular health state [1-4]. Moreover, CRI decreases together with GMA index variations have been analyzed with regard to heart rate (HR) and beat-to-beat heart rate (RR) interval variations. RR intervals and HR showed opposite correlations which proved the reliability of the conducted measurements. The most interesting and common result that has been revealed is that HR and RR interval variations appear to be connected to geomagnetic disturbances and CRI variations. The effects are more pronounced for high levels of GMA and strong CRI decreases [3].

Verma [5] reported that solar activity parameters (sunspot numbers, solar flare index, coronal index, CRI) are significantly connected with yearly suicide incidence during the period from 1989 to 2011. The Cornelissen et al. paper [6] on exploring any non-photic as well as photic components in the spectrum of the incidence pattern of suicides, reports the gender differences in Minnesota, USA, and Australia, notably in the para-annual range of the spectrum. The links between solar activity and cardiovascular diseases have been studied too [7-9].

The paper by Palmer et al. [10] summarizes the research undertaken in the field of heliobiology, focusing on the effect of variations of geomagnetic activity on human cardiovascular health. The three conclusions are that geomagnetic effects are more pronounced at higher magnetic latitudes; that extremely high as well as extremely low values of geomagnetic activity seem to have adverse health effects and that a subset of the population (10–15%) is predisposed to adverse health effects due to geomagnetic variations. Results of the paper by Gordon and Berk [11] support the hypothesis that a geomagnetic

storm activity is associated with suicide rates, in both male and female population in South Africa.

The aim of this study is to explore possible links between suicide incidence in Slovakia and in Czech Republic and heliophysical parameters on yearly basis.

Data and Analysis

Time series datasets consist of annual male, female, total and rate suicide incidents (per 100,000 population) in Slovakia and in the Czech Republic. The data of suicide incidence in Slovakia has been taken from the National Health Information Center (NHIC) [12,13], the data in the Czech Republic has been taken from the Czech Statistical Office (CZSO) [14]. Data are plotted in Figure 1. Monthly means of sunspot number (SSN) data were obtained from NASA, available at http://solarscience.msfc.nasa.gov/greenwch/spot_num.txt and average annual data computed. Daily mean of Ap-index data were taken from the British Geological Survey (http://www.geomag.bgs.ac.uk/data_service/data/magnetic_indices/apindex.html) and average annual data computed. Monthly averages of Solar 10.7 cm radio flux data were obtained from the NOAA, currently also online (ftp://ftp.geolab.nrcan.gc.ca/data/solar_flux/monthly_averages/solflux_monthly_average.txt) and average annual data computed. Hourly pressure corrected data of the CRI were obtained from the online data base of Lomnický štít Neutron monitor (<http://neutronmonitor.ta3.sk/>). Data are displayed in Figure 2.

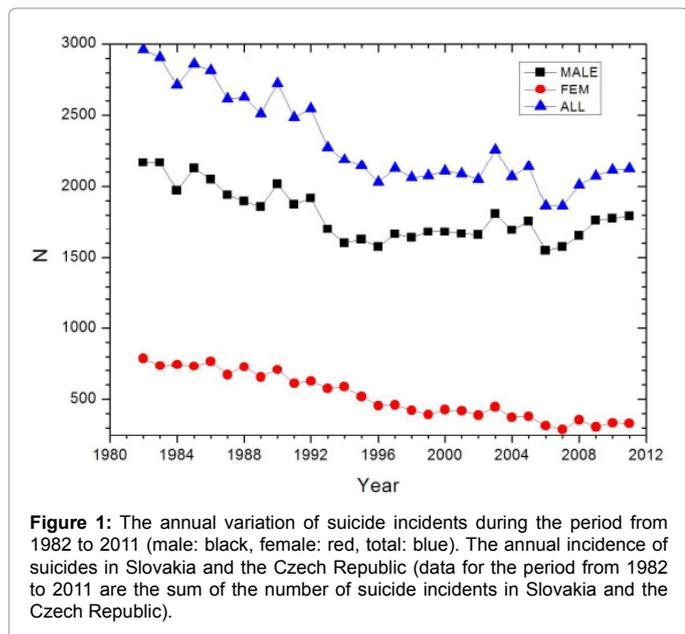
As a first step we computed the linear correlation coefficients between suicide event occurrence and the outer space physical data

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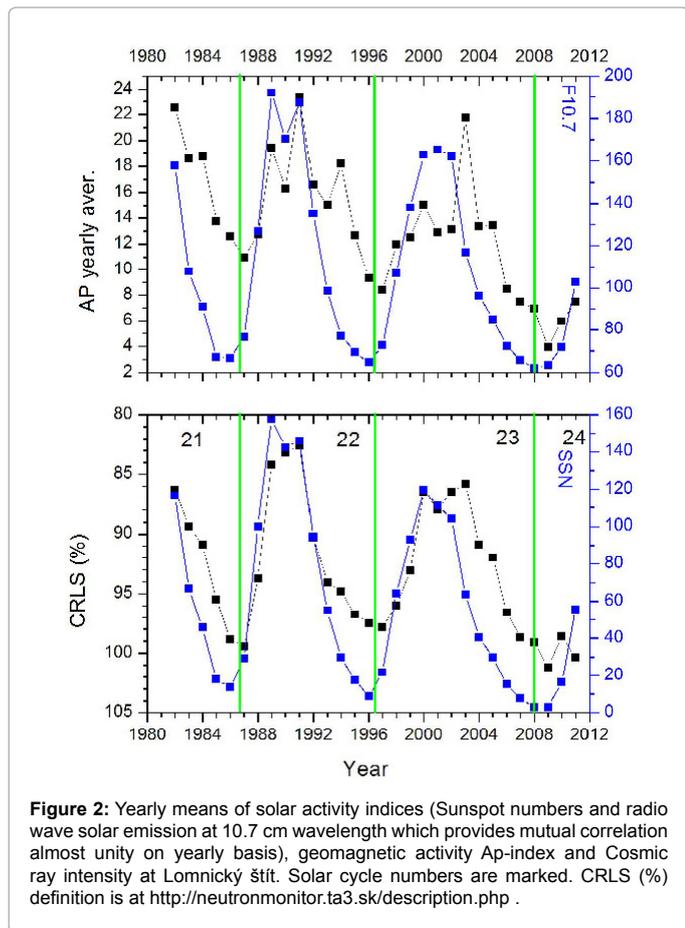
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analyzing large sample of the data over 1999-2010 in Japan, found that for males the number of suicides was associated with the monthly mean geomagnetic activity K index, but for females it was not the case. Recently, the importance of the background magnetic field for suicides was stressed in paper by Nishimura et al. [17]. A hypothesis that stronger geomagnetic field affects the number of male suicides, based on detailed dtstidicsl study in various regions of Japan, was presented. In our case (lower statistics and yearly time resolution) we are unable to infer the differences for males and females. For Ap the significance of the differences between two correlation coefficients provides rather high value $p=0.20$.

Although there is a high degree of correlation between the solar activity indices, cosmic rays and geomagnetic activity, the differences are also seen in Figure 2 at least in two aspects: a. cosmic ray delay (hysteresis in the declining phases of solar activity, especially in the cycles 21 and 23 – due to drifts of cosmic rays and different polarity of the heliospheric magnetic field – since CR reflect the “global” state of the heliosphere, not only its inner region), b. Ap local maxima as in year 2003 (may be reflecting the extreme geomagnetic events in October – November of that year) is not clearly seen in the solar activity yearly averages. Thus the linear multiple regression of N ALL with respect to variables AP, CRI and SSN has been performed (Figure 3).

Assuming low number of points (30), the statistical significance (Table 1 and Figure 3) is not high. Geomagnetic activity index provides the best correlation (Table 1). The linear multiregression method provides higher correlation coefficients. While solar (SSN, F10.7), heliophysical (CRI) and geomagnetic (Ap) indices show almost

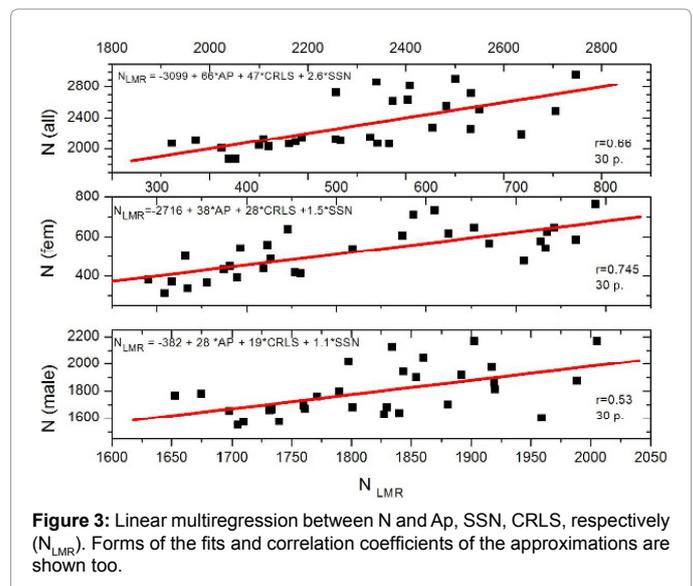


(Table 1). The statistical methods of computation the linear correlations used here are described in the book by Kenny [15].

Higher r is obtained in all three subsets for the correlation with geomagnetic activity index Ap. Recently, paper by Tada et al. [16]

	Male	Female	Total	N/10 ⁵ Number per 10 ⁵ population	p (N/10 ⁵)
CRI	-0.303	-0.346	-0.340	-0.335	0.07
SSN	0.290	0.344	0.332	0.336	0.07
Ap-index	0.487	0.642	0.589	0.607	0.0004
F10.7	0.226	0.251	0.250	0.255	0.17

Table 1: Linear correlation coefficients (r) between suicide incidents and cosmic ray intensity, sunspot numbers, Ap-index and 10.7 cm radio flux. Using $t = r / \sqrt{[(1-r^2)/(n-2)]}$ and testing the null hypothesis that the observed value comes from a population in which $\rho = 0$ we obtain p (in the last column for the values Per100,000 population, using the calculator available at <http://vassarstats.net/rsig.html>).



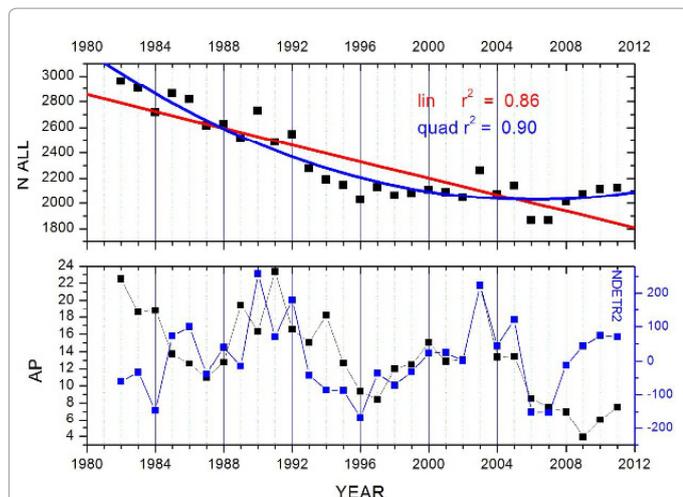


Figure 4: Upper panel: total number of incidences (N ALL) and time detrending. Values r^2 indicate quality of fits. Lower panel: quadratically detrended NDETR2 (scale to right) and Ap (scale to left).

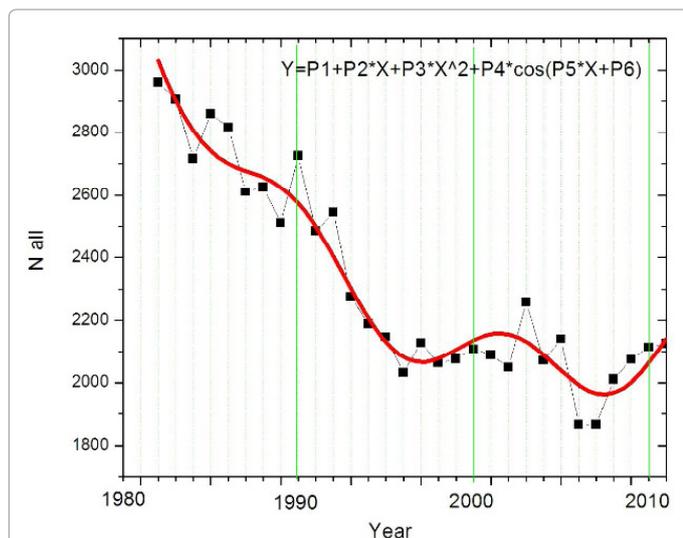


Figure 5: Best fit of the form given in the corner of figure. P1-P3 are taken the same as in Figure 4; $P4=87 \pm 23$; $P5=0.53 \pm 0.03$; $P6=1.59 \pm 0.26$. The estimate of contribution of the cyclicity revealed with respect to detrended data is (according to ratio of the amplitude of the harmonic to the characteristic value of N) of the order of 2-3%.

stationary time series, the suicide event number(s) time profiles include clearly the long term trend(s). To detrend the time series we used linear and quadratic approximation illustrated in Figure 4.

Detrending the time series of suicides incidence (NDETR2) shows some similarities with Ap (and also with CR and SSN too). The time detrending itself leads to rather good fit. Thus there is present probably a significant longer time component of the variation of incidences than only that corresponding to cyclicities of solar, geomagnetic and cosmic ray intensities (most pronounced ~ 11 year), which is not related to heliophysical variability.

Discussion

To identify a possible contribution of the harmonic signal(s) with the frequency around that of the solar cycle activity (and related

geomagnetic and cosmic ray intensities) to the profile $N(t)$, we performed the nonlinear curve fitting of the form $N(t) = P1 + P2*t + P3*t^2 + P4*cos(P5*t + P6)$, where t is time in years from 1982, $P5=2.0/T$, T is length of the cycle, and P1- P3 are taken from the fit in Figure 4 upper part. Assuming P4, P5 and P6 as variables, the best fit according to minimum χ^2/df (df is degrees of freedom) led to optimum values of P4-P6. For P5 as a starting point in optimization we took several values corresponding to T in interval (8,16) years. For such selections the result was stable and it converged to the best frequency $P5=0.53 \pm 0.03$. Figures 5 and 6 summarize the results.

Although the fit provides optimum for time of the cycle which is close to those of solar activity, geomagnetic activity and cosmic rays, it is not matching exactly the main cyclicity of ~ 11 years. Figure 6 presents the fitting details.

In comparison the profiles of χ^2/df of N' and SSN as a function of T_{per} , two different features are seen. First one is the different position of the best P5 fits: while for SSN it is ~ 11 years, for N' it is ~ 11.8 years. The second one is the difference in profiles of χ^2/df : for SSN the minimum is better pronounced, the decrease of χ^2/df is by a factor of ~ 20 , while for N' it is just ~ 1.5 (ratio of χ^2/df at $T_{per} = 8$ years to that at the optimum length of the cycles). Difference is also seen in Lomb-Scargle periodograms showing the normalized amplitude of power spectrum density as illustrated in Figure 7.

Dimitrov et al. [18] report also slightly higher cyclicity in suicide incidence rate (12.5 yr) than that of heliophysical parameters (Figure 2 of the cited paper). Figure 7 indicates also other features in the spectrum density of N profiles different from those of heliophysical parameters. The “high frequency” part of the spectra in N is different from those of SSN, CRLS and AP. The zoomed part of the spectra is revealing possible contributions. The highest one in the range $T_{per}=2 - 4$ years is that with the center at ~ 2.2 years. Such cyclicity was reported earlier in suicides in England and Wales based on data 1968 – 2002 [19].

Summary

The yearly data of suicide events occurred in Slovakia plus Czech Republic in 1982-2011 (N) have been compared with geomagnetic

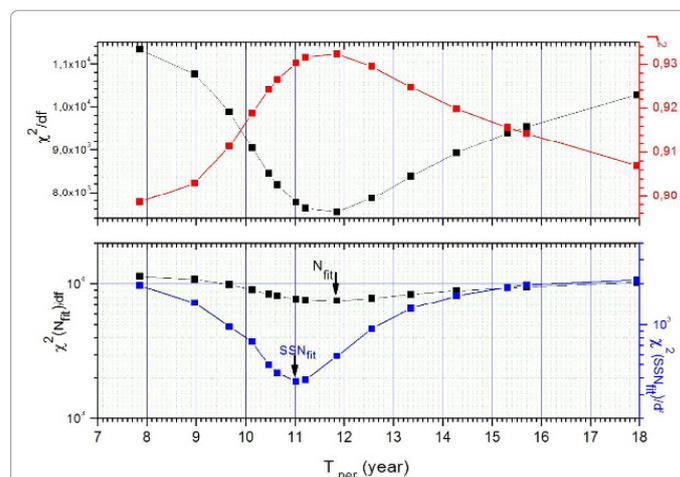


Figure 6: By fixing the values P1-P3 and checking χ^2/df as well as r^2 coefficient for several P5 values fixed (corresponding to $T_{per} = 2T/P5$), the optimum values P4 and P6, being the amplitude and phase of the cosine function, is found. The same procedure was done for the solar activity and other outer space indices. Lower panel displays the χ^2/df for the fits of N and SSN respectively in the logarithmic scale having the same range of values.

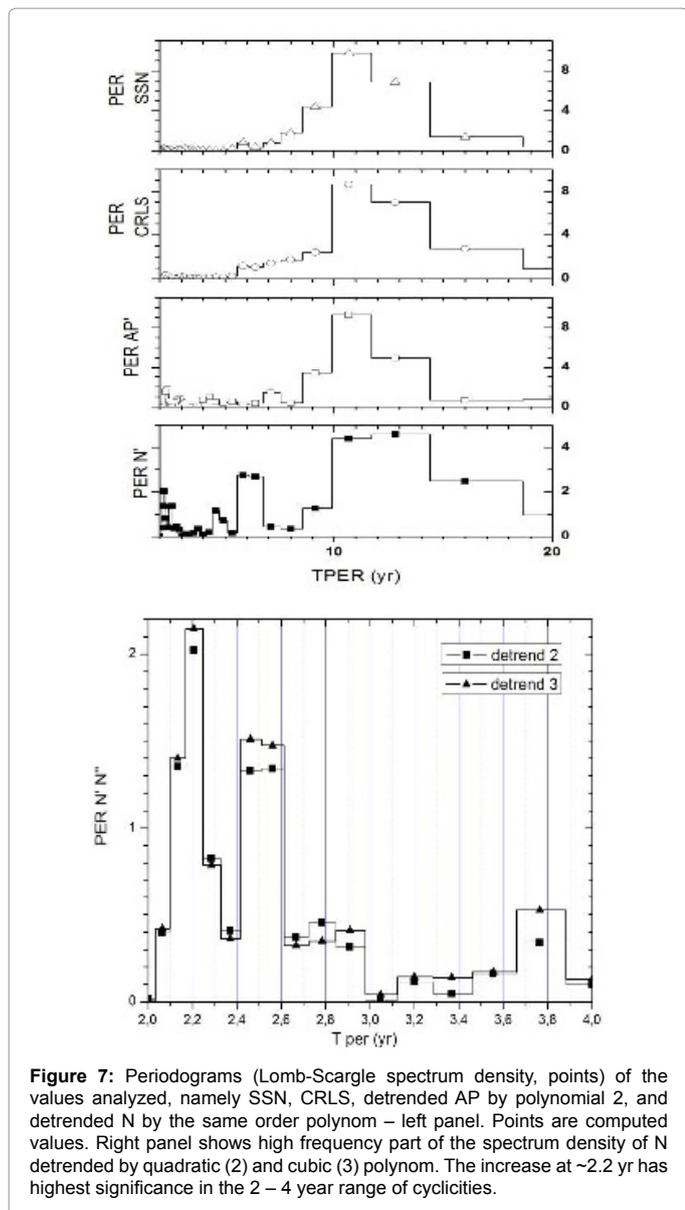


Figure 7: Periodograms (Lomb-Scargle spectrum density, points) of the values analyzed, namely SSN, CRLS, detrended AP by polynomial 2, and detrended N by the same order polynomial – left panel. Points are computed values. Right panel shows high frequency part of the spectrum density of N detrended by quadratic (2) and cubic (3) polynomial. The increase at ~2.2 yr has highest significance in the 2 – 4 year range of cyclicities.

(Ap), heliospheric (CRI) and solar (SSN, F10.7) activity indices. Rather weak linear relationship between heliophysical parameters and suicide incidents is found. The trends and linear correlation coefficients obtained can be marked as just based on the pairs of the data available and no causality is deduced. There may be also different factors influencing the suicide occurrence than just heliophysical ones (e.g. discussed by [20,21]). The results can be summarized:

1. Low number of points (30) and low statistics reveals the correlation coefficients between N and SSN, CRI having low statistical significance. The moderate one is found in comparison of N and the geomagnetic activity index Ap. Linear multiregression including all three indices provides slightly better correlations.
2. There is a long term trend persistent in the time series N (t). Low order polynomial fits in time significantly improve the correlations. Thus other, non-heliophysical influences probably play important role.

3. In detrended data N² the search of periodicities near the strongest one known in heliophysical data (~ 11 years) leads to identification of the cyclicity with the center at ~ 11.8 years and rather wide profile, not exactly matching the profiles of SSN, CRI and AP cyclicities.
4. Progress in the description and understanding the features in periodograms of suicide event occurrence (both spectral density and the phases) as well as in correlations with the outer space characteristics require better statistics, data from other regions (e.g. at various geomagnetic latitudes) and better temporal resolution.

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