"Physics of Auroral Phenomena", Proc. XXIII Annual Seminar, Apatity, pp.112-114, 2000

Polar Geophysical Institute

SURVIVAL STATISTICS OF PLANTS RESETTLED IN KOLA SUBARCTIC IS MODULATED BY HELIOGEOPHYSICAL EFFECTS

P.A.Kashulin, V.C.Roldugin*, L.L.Viracheva *(Polar Alpine Botanical Garden, *Polar Geophysical Institute, 184230 Apatity, Russia,* e-mail *roldugin@pgi.kolasc.net.ru)*

Abstract. The statistical analysis of multiannual vital statistics of more than four thousand resettled in Kola Peninsula herbivorous plant species under subarctic environment is carried out. Analysis of more then six decades of surveillance for mortality rate shows explicit deviations from Gompertzian vital statistics and extremely high fluctuations of mortality for some years. The comparison of mortality data with some heliogeophysical indices (sunspot number and Ap) showed a significant correlation between year-to-year mortality and Wolf numbers since middle 30-ies to middle 70-ies, which was higher compared to the correlation with Ap. The following abatement of correlation is explained by the rise of industrial factor effects on the plants, which determines the mortality pattern in the last years. The results suggest the modulation of plant survival physiological processes by heliogeophysical factors, the driving influence of those may be revealed under the background environment and the lack of high industrial load.

Introduction

The multiannual change in the running of biological processes in Subarctic shows the specific latitude dependent features at the different levels of structure organization that were described by many researches. Ordinary year-to-year changes in the behavior of various representatives of biota at the population level have most explicit manifestations in subarctic areas and often appear as regular fluctuation occurrences and temporal cyclic recurrences. These recurrences were registered in the course of lasting phenomenological natural surveillance both by general environmentalists and special researchers of terrestrial effects of solar activity. There were undertaken attempts to explain the wide list of latitude dependent phenomena ranged from sensitive to weak environmental effects subcellular biochemical reactions of unithiol oxidation [Gorshkov et al., 1966] to human multiple sclerosis latitude distribution in terms of heliogeophysical factors [Smirnova, Resch, 1996]. The solar activity cycles of about 10.5 and/or 21 years show a coherence with morphological, physiological and pathological processes in human populations, which were profoundly investigated and tabulated elsewhere [Breus et al., 1989; 1995; Halberg et al., 1999; Savitz et al., 1999].

The data regarding the solar modulation of mortality statistics in humans are quite controversial, yet this coherence relation seems to be geographically and latitude dependent. In auroral (50-70^{o} N) zone of the Europe as well as in Minnesota (USA) the mortality caused by cardio-vascular pathologies tends to be more pronounced, and in years of high vs. low solar activity it differs with statistical significance. At the same time, there was no significant difference in overall human mortality over the past three decades in Minnesota [Breus et al., 1989; Halberg et al., 1999; Savitz et al., 1999].

In contrast to human beings, both aging and mortality statistics in plants as well as questions regarding the involvement of environmental factors in these processes are poorly understood until now due to the lack of relevant investigations and available data on mortality in natural environment.

Results and discussion

In contrast to the wild environment, the cultivation of plants in conditions of special nurseries allows us to provide the strict controlled observation and regular registration of seasonal rhythms and the vital description of samples. The vital statistics data take its onset in 1932 since the foundation of the Polar Alpine Botanical Garden when experiments with introduction of alien plant species were started. During the overall surveillance period there were tested more then 3 thousands of herbivorous plant samples of different origin and living forms.

Earlier it was found that the senescence processes and aging in plants, resettled to the Subarctic area tend to be retardating. The survival of normal unexploited population of any living organisms is fitted best by Gompertz-Makeham statistics [Gavrilov and Gavrilova, 1991]. The inclusion of environmental factor effects is taken into account via special additive background parameters. Nevertheless, some years are characterized by unusually high fluctuations of plant sample fallings out due to their premature mortality, and there was evident incompatibility with Gompertz-Makeham statistics. The yearly plant sample death events were registered as annual total sum at the beginning of every summer. The preliminary rough analysis of multiannual data shows the extremely high mortality rate for some years. For examples, these were the following years: 1939-1941, 1948-49, 1958, 1969, 1987, 1993-1994. To describe this phenomenon, we have proposed a special index, which is equal to the ratio of the number of annual death events in a population to its current size. This index has a sense of mortality intensity and may be treated as a multiannual hazard factor for plant survival. The special consideration shows that temperature fluctuations and other meteorological factors can not explain the mortality peaks. Thus, during the period 1932 to 1939 a steady rise of mortality rate took place inspite of the fact the temperature was changed and summer mean values fluctuated following a random pattern.

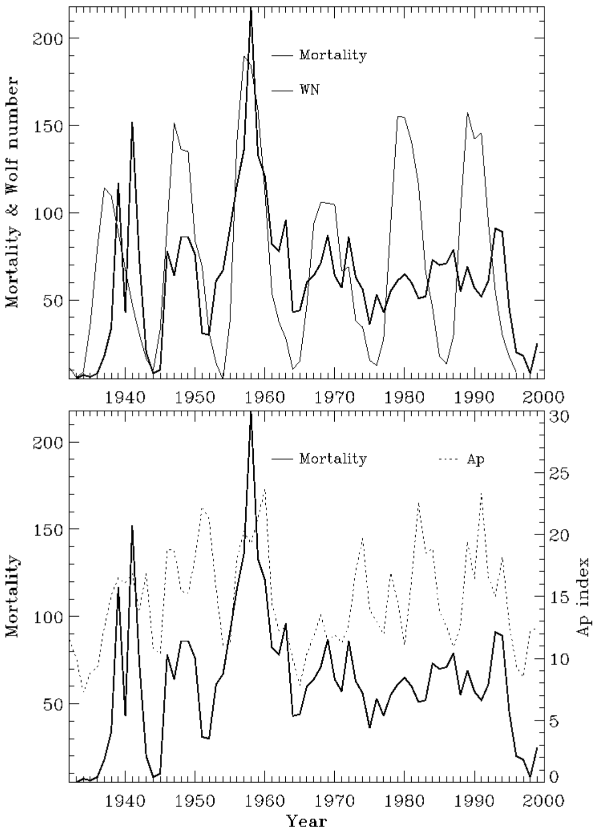

Fig. 1. Long-term mortality index variation (thick lines) together with Wolf Number (top panel) and Ap index (bottom panel).

It is traditionally accepted that the most severe hazard factor for the plant survival is a sudden summer frost which sometimes occurs under extreme subarctic and subalpine mixed environment of the experimental plots (300-400 a.s.l.). The most pronounced summer frost seasons were not followed by the rise of mortality in the current and next years, and the number of frost summer events did not correlate with hazard factor either, or, sometimes, even correlated negatively as it was in the 50-ies.

The common multiannual curve of mortality rate is presented in both panels of Fig. 1. As it is seen from the plots, some years are characterized by extremely high peaks of this index, which tends to be repeated. In attempts to explain the cyclic pattern of the obtained mortality curve, the data were compared with some indices related to the solar activity.

The comparison of the mortality data with Wolf numbers (WN), see top panel of Fig.1, has shown rather a high level of correlation (***k*** = 0.74±0.21) for three solar cycles from the 1943 up to the mid 70-ies. It is a noteworthy fact that the 17, 18 and 19th cycles are characterized by explicit coincidence with mortality peaks and the highest mortality registered level for all surveillance period was in 1958 (19th cycle) during the highest WN values throughout the whole period of their registration. The delay of mortality versus WN during 17th cycle is explained by starting conditions of the introduction works. During the following period from the mid 70-ies up to present, the peak-to-peak correspondence of the extreme mortality fluctuations with solar activity maxima was not found, and the mortality changed randomly without explicit high peaks. Thus, the correlation coefficient between WN and mortality for the whole plant surveillance period was equal to 0.44±0.13. The comparison of mortality index in years of extreme solar activity, i.e. WN= 108±43, with the data in the years of minimum activity WN = 22±17 reveals the difference between these two classes of mortality data with the probability of significance equal to P > 0.95.

In Fig.1 the comparison with Ap index is presented on the bottom panel. It is a planetary magnetic index and it shows the magnetic disturbance level between the 46° and 63° north and south geomagnetic latitudes. The correlation coefficients for 1932-1975 and 1932-1999 are equal to 0.41±16 and 0.27±0.13 respectively. The Ap index correlates with the mortality index worse than WN.

In Fig. 2 the crosscorrelation functions between WN and the mortality are shown for two periods 1932-1999 and 1940-1976. On both sides of the zero shift the name of the parameter shifted ahead of the other is depicted. The standard error is shown by the vertical bar. One can see that the correlation is higher for the second period. In this time span the maximal correlation takes place without a delay or when WN shifted a year ahead of the mortality.

The analogous picture for Ap is shown in Fig. 3. We use here Ap indices for summer months June – August. The maximal correlation coefficient is equal to 0.51±0.18 for the period of 1940-1976. The usage of yearly mean Ap index has resulted in the decline of correlation coefficient to 0.37±0.18. This result suggests that the highest susceptibility of plant organism to heliogeophysical effects takes place in the period of their maximum physiological activity. In any case, the dependence of plant biological response on its physiological state was shown in relation to weak artificial EM fields effects [Kashulin, Pershakov, 1995].

The correlation for Ap is better for the second considered period as for WN. However, the correlation coefficients for Ap are less than for WN, the both curves for Ap are too abrupt, and there is a meaningless shift of mortality ahead of Ap index. We suggest that an unidentified intermediate heliogeophysical factor is involved in the modulation of the mortality process, and its variation matches make more to WN as compared to the magnetic disturbance index Ap. As a whole, the results obtained show that the heliogeophysical factors related to the solar activity are involved in the processes modulating the plant survival during their adaptation under northern conditions of the Kola peninsula. The effect may be mediated by a number of unknown factors and the identification of bioactive agents is a question of special interest. In any case, the results suggest that the solar activity should be taken into consideration in the process of planning of plant introduction works to forecast the future unfavourable seasons for plant survival.

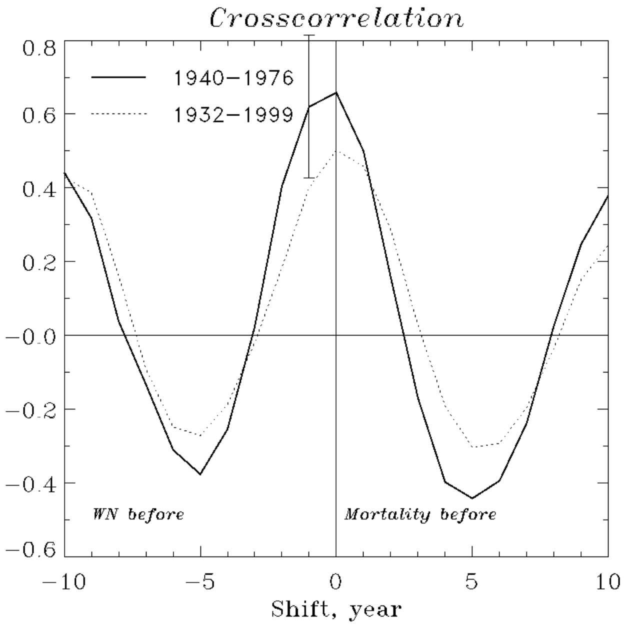

Fig. 2. Crosscorrelation curve for the mortality index and Wolf Number.

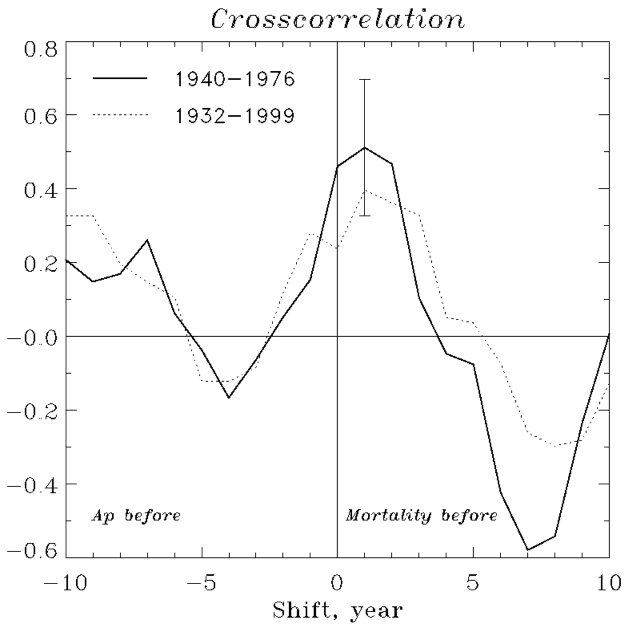

Fig. 3. Crosscorrelation curve for the mortality index and Ap index.

Of special interest question is the change of temporal pattern of mutiannual mortality in the middle 70-th. The possible explanation of this change is related to the rise of industrial environmental load from neighboring factories and, i.e., first of all, airborne pollutants of “Apatite” Joit-Stock Company and the local heating power plant. Particularly, the drastic rise of mortality in 1993-1994 was seemingly induced by the high level of emission in 1992, including sulfur dioxide from these sources. Thus, the total pattern of plant mortality is considered as a result of intrinsic interference of various factors, with prevalence of either heliogeophysical or industrial ones in different periods.

References

Breus T.K., Komarov F.I., Musin M.M., Naborov I.V., Rapoport S.I. Heliogeophysical factors and teir influence on cyclic processes in biosphere. Itogi Nauki i Techniki: Medicinskaya Geografia. V. 18. M.: VINITI, 1989. P. 138-142, 145, 147, 172-174 (in Russian).

Breus T., Cornelissen G., Halberg F., Levitin A.E. Temporal associations of life with solar and geophysical activity. Annales Geophysicae. 1995. V. 13. No 3. P. 1211-1222.

Gavrilov L.A., Gavrilova N.S. Historically stable indices of mortality and their use for medical geography // Geogr. Med. 1984. V. 14. P. 305-306.

Gorshkov E.S., Ivanov.V.V., Sokolovskaya T.M., Sokolovsky V.V., Troshichev O.A. Some perculiarities of unithiol test in conditions of the far North // Relations of biological and physico-chemical processes with space and helio-geophysical factors. P. 55-56.

Halberg F., Cornelissen G., Holley D., Schwarzkopf O. Chronoastrobiology and chronobioastronauitics: position paper // Cosmic ecology and noosphere. B.Vladimirsky, V.Berzhansky (eds.) Partenit, 1999. P. 9-22.

Kashulin P.A., Pershakov L.A. Experimental investigation of the conditions of the magnetosphere of the Subarctic as a possible exogenous factor for the northern biota // Biophysics. 1996.V. 40. No.4. P. 765-767.

Savitz D.A., Liao D.P., Sastre A., Kleckner R.C., Kavet R. Magnetic field exposure and cardiovascular disease mortality among electric utility workers // Am J. Epidemiol. 1999. V. 149. P. 135-142.

Smirnova N.A., Resch J.M. Geophysical aspects in the problem of multiple sclerosis prevalence. In: Relations of biological and physico-chemical processes with space and helio-geophysical factors. Pushchino, 1996. P.41-42.