"Physics of Auroral Phenomena", Proc. XXIX Annual Seminar, Apatity, pp. 295 - 298, 2006

Polar Geophysical Institute

SHORT-TERM CYCLES IN TERRESTRIAL ECOSYSTEMS AND POSSIBLE BIOLOGICAL SIGNIFICANCE OF QUASI-BIENNIAL OSCILLATIONS

P.A. Kashulin, N.V. Kalacheva *(Polar-Alpine Botanical Garden-Institute, Apatity, Russia)*

Abstract. The short-term cycles in the dynamics of population parameters for some terrestrial ecosystems with a possible role of quasi-biennial oscillations (QBO) and associated with them geophysical processes in the driving of 2-3 year population cycles of various representatives of biota are investigated. All biological phenomena considered are synchronous in the large-scale geographical areas which suggest the external modulation of their long-term dynamics.

Introduction

The utmost significance of the near 11 yr or near 23 yr cycles for biological systems are commonly accepted in heliobiology and the related biosciences. Unfortunately, there is much less available information regarding the possible biological consequences of the 2-3 yr cycles widely known in geophysics. As in geophysics, in biological systems these cycles can be regarded as a "fine" component of the most pronounced 11 yr cycles and hence expected to be less explicit and detectable. The quasi-biennial oscillations (QBO) being the main component of the solar activity variation determine the fine structure of the 11-yr solar activity cycle including its widely known bimodal pattern. The QBO presumably can control several important geophysical properties of the middle and low atmosphere including temperature and some chemical processes related to absorption of solar UV (Kononovich, Shefov, 2002). Among the most important and QBO dependent biological factors there could be considered solar UV radiation, $\Delta F_{10.7}$ and other associated with them optical, temperature, and chemical properties of the atmosphere at different Earth latitudes. Periods of $T_1 = 24.46 \pm 2.47$ months were found also in the proton fluxes of galactic provenance daily means density on board the orbital "MIR" station (Tsetlin et al., 2002).

Meanwhile, the relatively short-term cycles are widely distributed in the biological world. Moreover, the analysis of the dynamics of population of several biological indicator species over the last decades reveals the appearance of 2-3 yr components in the northern ecosystems where they had not been registered before. The aim of the paper is brief analyses of the most known short-term cycles in biological systems presumably controlled by either QBO or any other geophysical processes associated with them.

Biological data and their analysis

The 2-3 yr cycles were found in year-to-year dynamics for variation in the annual crop yield of Japanese beech *Fagus crenata* since 1990 yr in the genuine shore forest at SW Hokkaido (Fig. 1). Mast seeding is the periodic synchronous production of extremely large seed crops. This species *F. crenata* is widely used as an indicator species to monitor the mast seeding phenomenon among arboreal plants. The periodic fluctuations in seed crop were synchronous for five remote and separated one off another points (Yasaka et al., 2003).

The flowering of indicator plant species can be used as sensitive indicator for environment and climate changes. The monitoring of several species in various points of Northern Fennoscandia and Kola Lapland reveals the sustainable 2 yr components in the flowering onset time-course for the representatives of different taxonomic groups. Among them there were indicator species as follows: *Vaccinium vitis-idaea, V. myrtillus, Linnea borealis, Ledum palustre, Sorbus gorodkovii, Calluna vulgaris etc.* Flowering coherence for various species sustains two yr pattern between remote geographic points separated by several hundred kilometers, despite their various climatic and environmental conditions for vegetation. In Fig. 2 the time series for flowering onset are presented for, respectively: Polar-Alpine Botanical Garden-Institute (PABGI, 67°39'N, 33°37'E), Lapland State Biosphere Reserve (LSBR, 67°38'N, 32°38'E), Kandalaksha State Nature Protection Reserve (KSNR, 67^o 07' N, 32^o 38' E), "Pasvik" Reserve (68^o 99' N, 28^o 96' E), and Ecological Centre "Svanhovd" (Norway) (69^{o}27' N, 30^o 04' E). At all five monitoring points, all the plant species used as a general way started flowering coherently, the degree of which for some species was abated as the distance separating them increases.

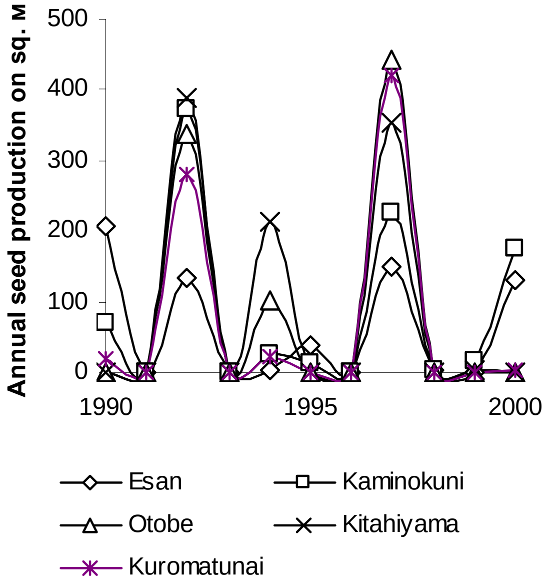

Fig.1. The mean seed number (n/m^2) for Japanese beech *F. crenata* in genuine forest at SW Hokkaido (depicted by authors according to different table data of appendix to Yasaka et al., 2003)

The two year cycles were described in temperate Russian European zone for *Padus* genus flowering long-term series since 50th of the last century (Minin, Gamburtsev, 2002); in both Pacific and European circumpolar *Salmonidae* population sizes (Sobko, 2002); in microtine voles population sizes in temperate and southern zones throughout the Earth (Börnstad et al., 1998; Stenthes, Saitoh 1998; Stenthes, 1999).

The human populations also may undergo alike cyclic changes. There should be pointed out some demographic indices, e.g. the mortality rate in the USA for the most aged classes and in many other countries caused by cardio-vascular diseases, flue, pneumonia, and cancer (Petukhov, 2005). The important example of the large-scale two years dynamics in biological systems is medical history for measles propagation in Europe. Before the vaccination program starts, measles in England and Wales were dominated by two-year cycle, with large outbreaks every second year (Grenfell, Harwood, 1997). These outbreaks were very much in synchrony throughout the area studied (Bolker, Grenfell, 1996; Ripa, 2000). When the vaccination started, the dynamics stabilized and synchronism was lost which supports the natural provenance of this virus dependent disease.

The generative productivity of *Vaccinium* genus plants in northern Fennoscandia over many years of monitoring shows explicit cyclicity with recurrent masting years which takes place every 4-5 years (Selås, 2000). However, a modern tendency in the year-to-year generative productivity dynamics for this species was the appearance, since 1989, of a new sustainable and dominated 2-3 yr component in the central area of the Kola Peninsula (Isayeva, 2001).

At least some of the listed phenomena seemingly could be explained by tendency in stratospheric ozone depletion and respective UV-B component in the ambient solar spectrum (World Meteorological Organization, 1999).

The essential drop in stratospheric ozone was observed at temperate latitudes since 1992 yr. The problem of stratospheric ozone dependent UV-B radiation turns into an acute problem actually over the last decades in relation to possible multiple consequences for terrestrial and water systems in the Arctic. Significant stratospheric ozone depletion was detected both in the Antarctic (Farman et al., 1985; Newman, 1999), and in some Arctic regions (Hansen et al., 1997; Shindell et al., 1998). Arctic regions accept less radiation as compared to low latitudes due to the solar zenith small angle and the respective thickening of ozone layer. Thus, it can be suggested that QBO, that affected the stratospheric ozone were of relatively higher weight in equatorial and temperate zones as compared to the northern ones. This scheme provides the base for explanation of the existence of geographical gradients in parameters of population dynamics of a great number of indicator species. The most known latitude dependent groups include some forest animals including small mammals and microtine rodents. For instance, the grey-sided vole *Clethrionomys rufocanus* shows the explicit gradient in population dynamics parameters in the most investigated Earth regions of Finland, where the 4-5 yr period in multiannual population size time-course in Northern Lapland turns to 2 yr period cycles in the south of Finland. Analogous latitude dependent patterns in small mammal dynamics are found in other European and Asian region.

On the other hand due to the same reasons the relative increases in UV-B observed for the last years in the circumpolar regions could be very high. In turn, the extremely high fluctuations in ambient UV radiation relative changes could be much more important for living systems as compared to its absolute levels [Björn et al., 1997].

Conclusions

Taking into consideration these known features of adaptive reactions of living systems to the ambient UV radiation one can explain a great number of biological phenomena at the population level of terrestrial ecosystems. Some of the most important are as follows: the phenomenon of large-scale geographical gradients in small mammals population year-to-year dynamics period cycles found in the northern hemisphere; the conservative inherence of 2-3 cycles in the long-term dynamics of many ecosystems; contemporary tendencies which appear as new explicit 2-3 yr trends in the dynamics of generative processes in various boreal and arctic indicator herbaceous and arboreal plant species.

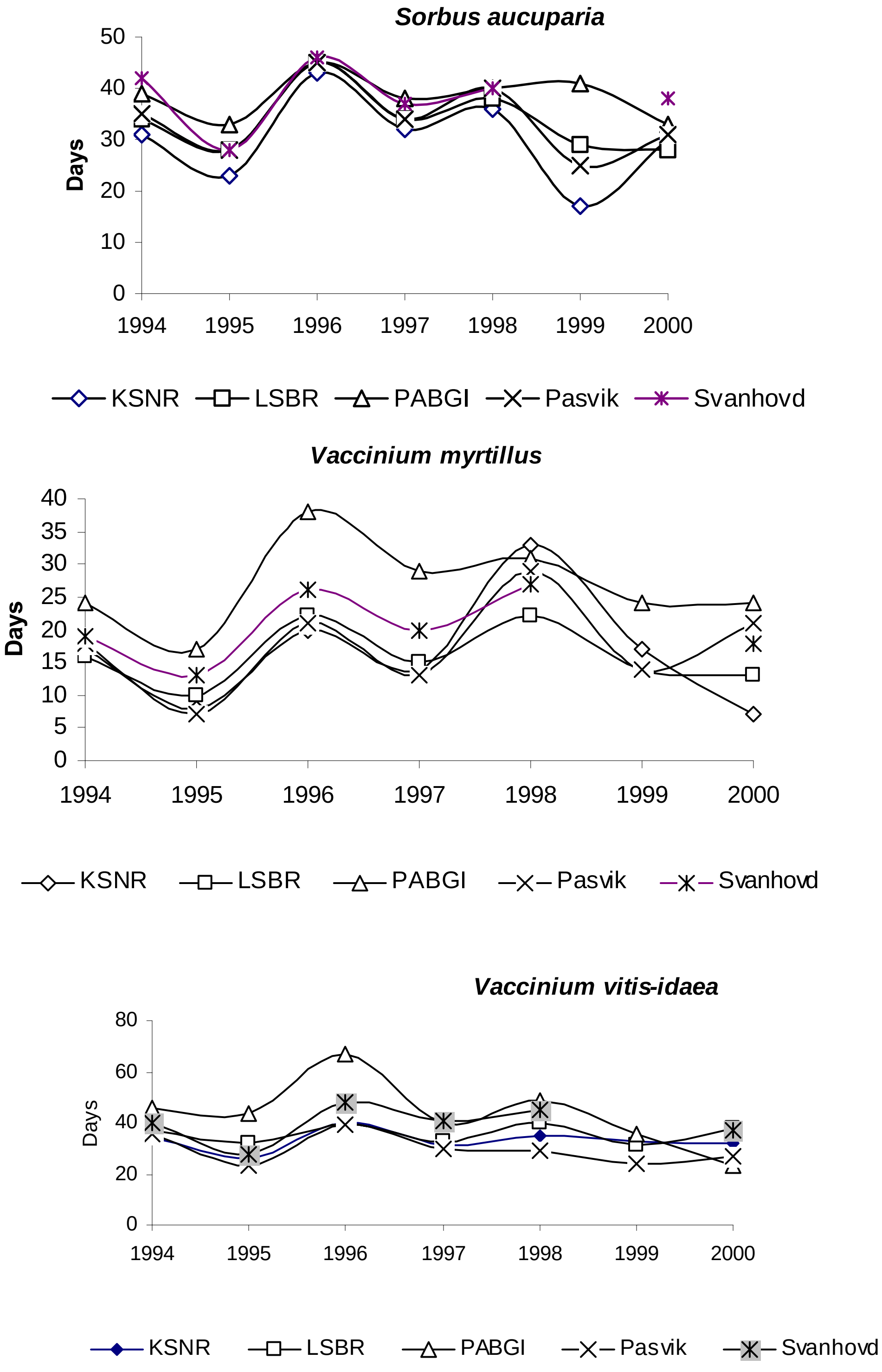

Fig. 2. The flowering onset for *Vaccinium vitis-idaea, Vaccinium myrtillus, and Sorbus aucuparia at* five separated points of Northern Fennoscandia and Kola Lapland. Days were counted from the 1st June.

The both former short-term and novel 2-3 yr period trends are presumably related to QBO via a number of environment intermediates and/or by associated with QBO factors. As a concluding remark it should be emphasized that all the described cyclic biological phenomena ran synchronously in large geographical areas, which suggests the involvement of external periodic driving processes.

References

Björn L.O., Callaghan T.V., Gehrke C. Effects on subarctic vegetation of enhanced UV-B radiation. In: Lumsden P (ed) Plants and UV-B: responses to environmental change. Cambridge University Press: Cambridge, 1997. P. 233-246.

Börnstad O.N., Stenseth N.C, Saitoh T., Lingjasre O.C. Mapping the regional transitions to cyclicity in *Clethrionomys rufocanus:* spectral densities and functional data analysis // Researches on Population Ecology. 1998. V. 40. P. 77-84.

Bolker B. M., Grenfell B. T. Impact of vaccination on the spatial correlation and persistence of measles dynamics // Proc. Natl. Acad. Sci. USA. 1996. V. 93. P. 12648-12653.

Farman J.C., Gardiner B.G., Shanklin J.D. Large losses of total ozone in Antarctica reveal seasonal ClO_x/NO_x interaction // Nature. 1985. V. 315. P. 207-210.

Grenfell B. T., Harwood J. (Meta)population dynamics of infectious diseases // Trends Ecol. Evol. 1997. V. 12. P. 395-399.

Hansen G, Svenoe T., Chipperfield M.P. et al. Evidence of substantial ozone depletion in winter 1995/ 96 over Northern Norway // Geophys Res Lett.1997. V. 24. P. 799-802.

Isayeva L.G. Dynamics of fruit yield for *Vaccinium myrtillus* L. in the central part of Kola Peninsula. Plant resources. 2002. V. 38. No 2. Pp. 55-65. (In Russian)

Kononovich E.V., Shefov N.N. Quasi-biennial variations of the solar activity during 11-year cycle and their display in the variations of the temperature in middle atmosphere // Physics of Auroral Phenomena. Proc. of Annual Int. Sem. Polar Geophys. Inst.: Apatity, 2002. P. 143-146.

Minin A.A., Gamburtsev A.G. Phenological events in nature of middle European Russia / Atlas of Temporal Variations in Nature, Anthropogenic and Social Processes. V. 3. M.: Yanus, 2002, Pp. 277-284. (In Russian)

Newman P.A. The Antarctic ozone hole. In: Todaro RM (ed) Stratospheric ozone, an electronic textbook. NASA Goddard Space Flight Center, Greenbelt. 1999. Hansen G, Svenoe T., Chipperfield M.P. et al. Evidence of substantial ozone depletion in winter 1995/ 96 over Northern Norway // Geophys Res Lett.1997. V. 24. P. 799-802.

Petukhov S.A. The links Sun - QBO - ozone layer - biological social time series data: practical application of 2 yr asymmetry indices for its investigation / Cosmos and Biosphere. Abs. of VI Int. Crimea Conf. 26 Sept. - 1Oct. 2005. Partenit, Crimea, Ukraine. 2005. C. 90-92.

Ripa J. Analysing the Moran effect and dispersal: their significance and interaction in synchronous population dynamics // Oikos. 2000. V. 89. P. 175-187.

Selås V. Seed production of masting dwarf shrub *Vaccinium myrtillus* in relation to previous reproduction and weather // Can. J. Bot. 2000. V. 78. P. 423-429.

Shindell D.T., Rind D., Lonergan P. Increased polar stratospheric ozone losses and delayed eventual recovery owing to increasing greenhouse-gas concentrations // Nature 1998. V. 392. P. 589-592.

Sobko V.G. Dynamics in population size of pacific Salmonidae. Atlas of Temporal Variations in Nature, Anthropogenic and Social Processes. V. 3. M.: Yanus, 2002, Pp. 432-435.

Stenthes N.Ch., Saitoh T. What do we know and what do we need to know more about the population ecology of the vole *Clethrionomys rufocanus*? // Res. Popul. Ecology. 1998. No 40

Stenseth N. Chr. Population cycles in voles and lemmings: density dependence and phase dependence in a stochastic world // Oikos. 1999. V. 87. P. 427-461.

Tsetlin V.V., Bondarenko V.A., Victorov V.A. et al., Variations in radiation and development of microbiota community at OC MIR in dependence of solar activity. Atlas of Temporal Variations in Nature, Anthropogenic and Social Processes. V. 3. M.: Yanus, 2002. Pp. 556-560. (In Russian)

World Meteorol. Organization. Sci. assessment of ozone depletion: 1998. Report N. 44. WMO, Geneva. 1999.

Yasaka M., Terazawa K., Koyama H., Kon H. Masting behavior of *Fagus crenata* in Japan: spatial synchrony and pre-dispersal seed predation // Forest ecology and management. 2003. V. 184. P. 277-284.