# The "Sun - climate" relationship. II. The "cosmogenic" beryllium and the middle latitude aurora.

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**Abstract.** In Paper I we pointed out that the subcenturial climate cycle with duration of 50-70 years could have solar reason. The argument was the existence of statistically significant respective cycle in the group sunspot numbers. In this Paper II we suggest additional evidences for the solar origin of the subcenturial climate variations. Two other indirect and mutually independent solar proxies are under studying: Greenland and Antarctic "cosmogenic" $^{10}Be$ concentration, as well as the number of the middle latitude auroras (MLA) in 18th and 19th centuries. The results could be summarized as follows: (1) Well pronounced 50-55, about 65 and about 120 yr oscillations exist in the Greenland data. (2) Relatively weak, but statistically significant 60-65 yr cycle and essentially more powerful 130 yr cycle is also discovered in the Antarctic data. (3) Strong 62-63 yr oscillations are found in the MLA, that is clear evidence for existing of 62-63 yr cycle in the most powerful solar phenomena - chromospheric flares and coronal mass ejections. (4) Relative good coincidence between the extremums of 62-63 yr cycle in the $^{10}Be$ concentration and the MLA events is elucidated. The last fact indicates that in the epoch of MLA maximum a significant part of $^{10}Be$ is most probably generated in the stratosphere by high energetic solar particles, as addition to the $^{10}Be$ generated usually by the galactic cosmic rays.

**Key words:** Sun, solar-climatic relationship, aurora

## Зависимостта "Слънце - климат". II. Космогенният берилий и полярните сияния на средни географски ширини.

Борис Комитов

В Статия I ние показахме, че субвековият климатичен цикъл с продължителност 50-70 г би могъл да има слънчева причина. Аргументът бе съществуването на статистически значим съответен цикъл на броя групи слънчеви петна. В тази Статия II предлагаме допълнителни аргументи за слънчевия произход на субвековите климатични вариации. Изследват се два други, косвени и взаимно независими индикатора на слънчевата активност: концентрацията на гренландския и антарктическия космогенен $^{10}Be$, както и броя на полярните сияния на средни географски ширини (ПССГШ) през 18-19 в. Резултатите могат да се обобщят както следва: (1) Съществуват добре изразени 50-55, около 65 и около 120 г осцилации в гренланската редица от данни. (2) Открити са относително слаб, но статистически значим 60-65 г цикъл и съществено по-силен, около 130 г цикъл в антарктическите данни. (3) Намерени са силни 62-63 г осцилация на ПССГШ, които са ясно свидетелство за съществуването на 62-63 г цикъл при най-мощните слънчеви прояви - хромосферните ерупции и короналните изхвърляния на маса. (4) Изявено е сравнително добро съответствие между екстремумите на 62-63 г цикъл в концентрацията на $^{10}Be$ и броя на ПССГШ. Последният факт индикира, че най-вероятно в епоха на максимум на ПССГШ значителна част от $^{10}Be$ се генерира в стратосферата от високо енергетични слънчеви частици, като добавка към $^{10}Be$, генериран обичайно от галактическите космични лъчи.

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## 1 Introduction

A significant feature of climate changes since AD 1700 is the existence of powerful subcenturial $\approx 60$ yr quasi-periodic oscillations both in the Northern Hemisphere and World Ocean temperature time series (Moberg et al., 2005; Parker et al., 1995). As it has been already pointed out in some studies these variations are well associated with the supercenturial tendency of the general solar activity upward and reflect on the increasing of the total electromagnetic solar irradiance (de Jaeger and Usoskin, 2006; Komitov, 2009 (Paper I)). These studies include the periods AD 1610-1979 and AD 1856-1995, respectively. The coefficient of correlation is $\approx 0.78$ for Northern Hemisphere temperatures and $\approx 0.88$ for the World Ocean.

The presence of subcenturial climatic oscillations are discussed in some "pure" climatological and meteorological studies (Schleissinger, 1993; Thompson, 1997). The origin of the latter ones is in the course that they are a result of inner auto-oscillations of the Earth's climate system (Schleissinger, 1993).

In Paper I it has been pointed out that subcenturial cycles with duration of 50-55 and 60-67 years are clearly visible after removing the corresponding regression models "sunspot activity - temperature" from the Northern Hemisphere and World Ocean temperature series. In these models the 11 yr smoothed group sunspot number has been used as a long-time sunspot activity proxy in relation to the corresponding smoothing values of both already mentioned temperature series. A well expressed $\approx 130$ yr cycle is also visible in the Northern Hemisphere residual series. A numerical experiment with the World Ocean temperature series point out that the general trend may be approximated with quadratic polynomial. After we remove them from the series, in the "residual" series a cyclic "doublet", corresponding to periods of 58 and 65 years, as well as $\approx 88$ yr cycle, are well visible.

These results demonstrate that a strong one or two component quasi-subcenturial cyclic variations with mean duration of $\approx 60$ years exist in the climatic data series. If the supercenturial upward trend is accounted as a regression model, where the increasing sunspot activity is taken as a factor, there could be derived two close to each other cyclic tendencies in the residuals by duration of $\approx 52$ and 65-67 years, respectively (see Paper I). If a polynomial expression of the trend is taken, then a nearly $\approx 60$ years two component cycle could be found in the residual series.

The main question that arises is are these subcenturial oscillations caused by inner auto-oscillations of the Earth's climate or they are generated by some outer cosmic factor.

In Paper I some evidences that the quasi 60 yr oscillations could have solar origin are given. Weak but statistically significant sunspot activity oscillations has been detected both in Wolf's ($R_i$) and Group Sunspot Number ($R_h$) series (Komitov and Kaftan, 2003). This leads to the assumption that the quasi-subcenturial climatic oscillations could be caused by specific processes on the Sun which are not so close connected with the overall sunspot activity, but with a specific relatively small part of sunspot groups or with specific coronal phenomena.

There are two types of solar factors forcing over climate which are discussed on this stage: the total solar irradiance (TSI) and the galactic cosmic rays (GCR) flux variations. The TSI flux causes less or high electromagnetic flux near to the Earth's surface and corresponds to cooling or warming of the climate. The GCR flux increasing during sunspot minimum epochs (known as Forbush-effect) could force the aerosols and clouds generation (Svensmark and Friz-Christensen, 1997; Yu, 2002). Both factors force the climate changes in one and the same direction simultaneously (warming or cooling) and their total effect is proxied by the overall sunspot index in the models "sunspot activity - temperature" (see Paper I). Therefore, the assumed additional climate changes, forced by solar factor, should have the following features: 1) A relatively low or absent correlation with the overall sunspot activity ($R_i$ or $R_h$ indexes) and that is way it is not taken into account in the regression models of the sunspot-temperature relationships. 2) A well expressed quasi-subcenturial cyclity with period $\approx 60$ years and eventually period of $120-130$ years too. 3) The influence of these factors should be relatively strong on the lower layers of Earth's atmosphere (the low stratosphere and troposphere) where all important for the meteorology and climate processes occur.

The most probable solar source of such climate changes could be the high energetic proton eruptions when particles with energies $E > 10MeV$ could be produced in active regions, during the powerful solar flares. In cases of $E > 1GeV$ the protons are able to penetrate very deep through the magnetosphere and atmosphere reaching the meteorological active low atmosphere and even the Earth's surface. These solar protons could cause increase in the aerosol and cloud generation like the GCR with the same energy. They could also affect the atmospheric circulation, known as effect of Brown, Willcox and Mansurov-Page (see Tinsley, 2000).

If such assumption is valid, a searching for specific geophysical solar determined phenomena as independent evidences, is reasonable. These phenomena should be related closer to the flare and coronal activity, as well as to the sunspot activity. In this course two types of geophysical phenomena are analyzed in this Paper II: the middle latitudes auroras (MLA) and the stratosphere production rate variations of the "cosmogenic" $^{10}Be$.

The MLA are generated by the high energetic solar particles during the most powerful solar flare events, including the coronal mass ejections (CME) too. Besides the GCR, the solar high-energy particles should be the second important source for "cosmogenic" isotope production in the stratosphere near to the epochs of high flare activity. The use of $^{10}Be$ data in the polar continental ice cores as indicator of these processes is, in our opinion, preferable because of the relatively easy and fast transport of this component from the stratosphere to the Earth's surface. The "resident time" (the needed time for the stratosphere-surface transport) of this process is relatively short, 1-2 years, i.e. unlike $^{14}C$ the $^{10}Be$ is almost directly related to the solar activity level for the corresponding epoch.

## 2 Data and methods

In this study two $^{10}Be$ data sets are used: 1. The "Greenland" series (Beer et al., 1990, 1998; Damon et al., 1997) and the "Antarctic" one (Bard et al., 1997). The first one is related to the epoch AD 1423-1985, while the second one includes AD 850-1900. By the use of mathematical procedure both series are resampled at equidistant time steps of 1 years for the "Greenland" series and 5 years for the "Antarctic" one. For the aims of our analysis the "Greenland" series turned out to be more interesting.

The Central Europe Middle Latitude Aurora Catalog of Krivsky and Pejml (1988) for the epoch AD 1000-1900 is published in the National Geophysical Data Center base
*ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA*. Because of the obviously poor information before AD 1700 only the data for the last two centuries (AD 1700-1900) has been used.

The used mathematical procedures are already described in Paper I.

## 3 Results and analysis

Both $^{10}Be$ series has been studied for existence of cycles by using the T-R periodogram procedure. The "Antarctic" series has been scanned by time step of $\Delta T = 2.5$ years, starting from initial period value of $T_0 = 10$ years up to 1000 years with a time series data step of $dT$=5 years. In the "Greenland" series a weak nonlinear trend has been removed in advance. The applied scanning time step of the T-R correlogram was $dT$=1 years, starting from initial period value of $T_0$=2 years. The calculated correlograms are shown in Fig. 1 and Fig. 2, respectively.

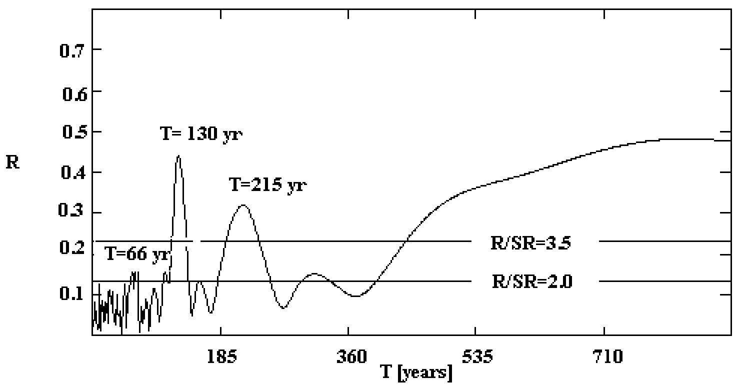


**Fig. 1.** The T-R correlogram of the "Antarctic" $^{10}Be$ series (AD 850-1900).

The most powerful cycle in the "Antarctic" series in the subcenturial and quasi-centurial range have duration of $\approx$ 130 years. There is also a weak quasi

66 yr cycle, which statistical significance is slightly over the critical 95% level ($R/\sigma(R) = 2.0$). The relatively powerful 215 years cycle could be taken as an analogue of the quasi-bicenturial solar cycle, which is already obtained in the $^{14}C$ tree ring concentrations (INTCAL 93, 98, 04) (Stuiver et al, 1998; Reimer et al, 2004), as well as in the Schove's series. A strong quasimillenial ($\approx$ 850 years) cycle-type tendency is also clearly detected.

As is shown in Fig. 2, the "Greenland" series is essentially richer of cyclic variations, in the range from 20 to 400 years, than the "Antarctic" one. The cycles with high statistical significance ($R/\sigma(R) > 3.5$, see Section 2 in Paper I) exist at 24 (the Hale cycle?), 40, 51, 66, 98, 125-140 (doublet), 192-216 (the bicenturial solar cycle), 272 and 384 years. The Schwabe-Wolf's cycle oscillation is weaker there, but it could be very clearly visible if all subcenturial or longer cycles ($T > 40$ years) are removed (Komitov et al., 2003).

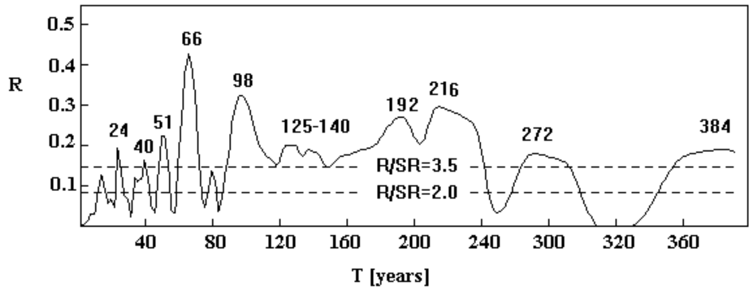


**Fig. 2.** The T-R correlogram of the "Greenland" $^{10}Be$ series (AD 1423-1985).

Unlike the Fig. 1, the 66 yr cycle is the most powerful in the "Greenland series", while the 120-130 yr one is in third place. Both results are not enough correct to be compared because there are two epochs with different lengths in both data sets. The problem about the influence of the epoch difference on the result will be analyzed below.

In Fig. 3 the annual number $N_{aur}$ of the middle latitude aurora events for the epoch AD 1000-1900 is shown. There is a clear visible separation of this series in two parts: very low annual numbers before AD 1700 and hard increase of the events number after that. In our opinion this effect is caused by a subjective factor. In the Middle Ages the interest in this phenomena was low and there is a lack of messages for the first 600-700 years. It should be also taken into account that many of the early messages could been destroyed or lost. On other hand, the epoch of the deep supercenturial solar minimums of Spoerer (15-16th centuries) and Maunder (17th century) could be related to a real deficit of aurora events. A superposition of subjective and real factors is possible too.

On other hand, regardless of the lack of data in the early part of the series, the supercenturial minimums of Oort (O), Wolf (W), Spoerer(S) and Maunder(M), as well as the Dalton minimum (D) in 19th century are clearly visible. We should also mark the fact of non-zero auroral activity even in the deepest part of Maunder minimum, where according to the instrumental data the sunspot activity has been almost absent (Hoyt and Shatten, 1998).

Mainly the recent part of MLA series (200 years, after AD 1700) has been used in our analysis because of the possible lack of data.

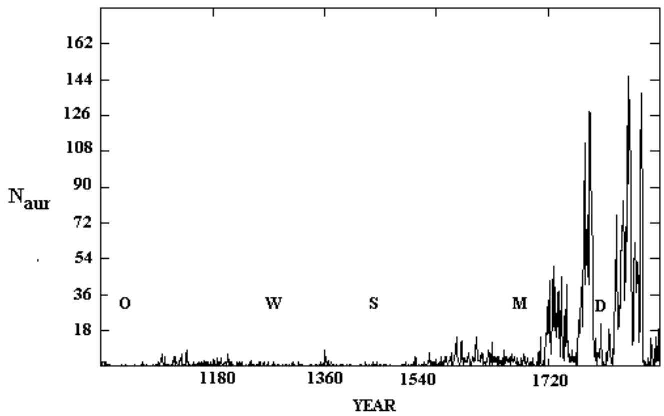


**Fig. 3.** The middle latitudes auroras (MLA) annual number (AD 1000-1900).

In Fig. 4. the T-R spectrum of this recent part of the MLA series is shown. The existence of very powerful quasi 62.5 yr cycle is the most important feature there. In second place, there is a quasi-bicenturial cycle ($T$ = 217 years). It is very intriguing that the analogs of solar sunspot Schwabe-Wolf's ($T$ = 10.25 years) and the magnetic Hale's ($T$ = 20 years) are very low, near to the "critical" 95% level ($R/\sigma(R)$=2.0).

The last result point out that the potential primary solar sources of MLA are distinguished by a powerful subcenturial ($\approx$ 60 years) cycle. This is also a strong indirect evidence that the climate oscillations with the similar duration could have most probably solar origin. The nature of these solar processes will be commented in the Discussion. The problem about the possible physical mechanism of the influence of these phenomena over the climate will be discussed in Paper III.

For the aims of our study it is essentially important to analyze the relationships between the dynamics of $^{10}Be$ ice core concentrations (and especially the "Greenland" series) and the MLA annual number series during and after Maunder minimum up to AD 1900.

As it is generally accepted, the stratospheric $^{10}Be$ production rates (as well as other "cosmogenic" isotopes) are in an inverse relationship to the solar

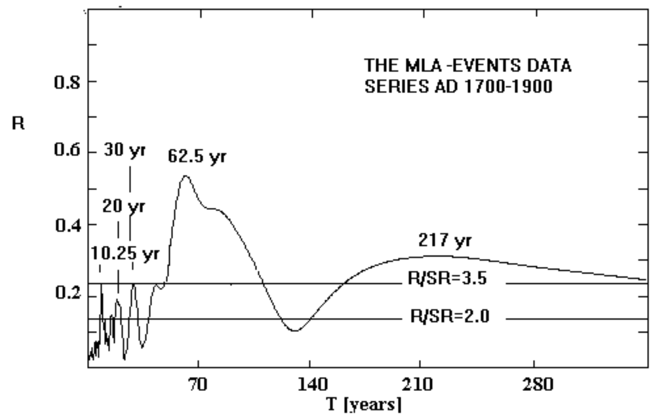


**Fig. 4.** The T-R correlogram of the MLA annual number series (AD 1700-1900).

activity (the "Forbush effect"). This is due to the fact that the penetrating Earth's atmosphere GCR flux is reduced by the solar wind during the epochs of solar activity maximums, decreasing the "cosmogenic" isotopes production rates in the atmosphere. By this phenomenon the existence of high "cosmogenic" isotope concentrations of $^{14}C$ in tree samples and $^{10}Be$ in continental ice probes are related to the epochs of the supercenturial solar minimums of Spoerer, Maunder, Dalton etc., or to Schwabe-Wolf's cycle minimums.

It is very interesting to compare the $^{10}Be$ dynamics with a geophysical phenomenon, such the MLA events. By one hand their maximums are associated with high solar activity, but on other hand they are distinguished by a quasi $\approx 60$ yr cycle that is non-typical for the sunspot activity.

Both series are shown in Fig. 5. The picture is very complicated. There are at least three epochs (AD 1720-1730, $\approx 1780$ and $\approx 1850$), where higher MLA annual numbers corresponds to high $^{10}Be$ concentrations as a long time tendencies. Also, the local low amplitude extremums of the 10-11 yr cycles in both series are in opposition, in good accordance with the "Forbush-effect" mechanism.

In this course it is interesting to note that the absolute $^{10}Be$ maximum for all "Greenland" series (563 years long) is placed away from AD 1690 (the deepest Maunder minimum phase) but $\approx 30$ year later at AD 1720-25. After AD 1700 the sunspot activity starts a slowly increasing phase. The sunspot maximums near to AD 1705 and 1715 are relatively weak, but very clearly established during the deepest Maunder minimum phase. In this course the increasing of MLA frequency after AD 1700 is reasonable, but why it coincides with a significant increase of $^{10}Be$ concentrations and why the maximum of last ones are shifted in $\approx 30$ years after the "normal" moment?

Two hypothesises are possible there. The first one is more "conventional": the increasing of the $^{10}Be$ production rates during the recent phase of Maunder minimum could be caused by Earth's climatic factor (Hypothesis

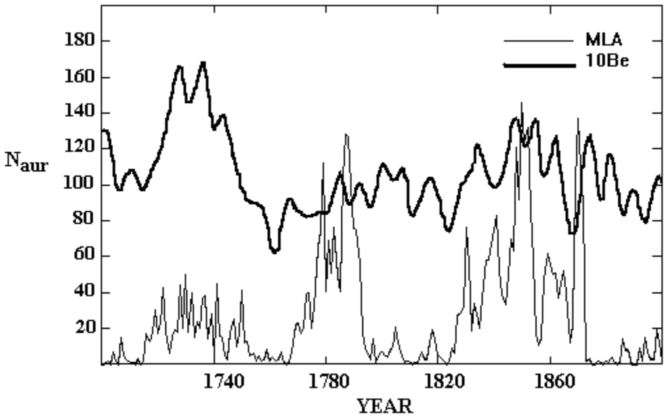


**Fig. 5.** The annual MLA events number (thin line) and "Greenland" $^{10}Be$ concentrations (bold line) series (AD 1700-1900). The presented $^{10}Be$ data are multiplied by factor of 50.

"A"). This is in accordance with the perceived viewpoint that in the $^{10}Be$ time series a significant "climatic noise" exists (Damon et al., 1997). However, we assume that a second factor could be also possible: the $^{10}Be$ production rates increasing is caused by powerful flare eruptions, causing coronal events as CME and high energetic protons ($E > 10$MeV) (Hypothesis "B").

The possible validity of hypothesis "B" could be tested with the help of the cross-correlation analysis. It needs that the best positive correlation coefficient $r$ should be shifted less than 2 years ($^{10}Be$ delay to MLA), which corresponds to the mean "resident time" for transportation of beryllium atoms from the stratosphere to the Earth's surface. This is in a case if we assume that all MLA events are produced by solar events with one and the same physical parameters (total flux and power) and the $^{10}Be$ "solar" component production rate should be proportional to the number of the last one per unit time as well as to the MLA number per unit time.

However, more realistic assumption is that the power and total flux of the separated solar events, which caused MLA, vary in a broader range and the most powerful flares with strongest effects over the Earth's low and middle atmosphere (as well $^{10}Be$ production) occur on the decreasing phases of Schwabe-Wolf's cycles. During these epochs the phenomena occur more rarely and they are often concentrated in relatively short periods. Simultaneously, they must be characterized by essentially higher energies. There are many examples in this course: the flare activity in August 1972, October-November 2003, September 2005, etc. By this reason it could be obtained that the best expected cross-correlation coefficients must lie in relatively broader range of 1 to 5-6 years delay of $^{10}Be$ to the MLA. The last limit corresponds to the typical lengths of the most active periods of the flares, 4-5 years after the

Schwabe-Wolf's sunspot maximums, plus the "resident time" of 1-2 years for $^{10}Be$.

We use a modified "moving window" procedure (see Section 2 in Paper I) to study the cross-correlation relationship evolution between MLA-events, which is as a proxy of the powerful flare activity events, and the $^{10}Be$ concentrations in the "Greenland" series. For a rough estimation of the conditions during the Maunder minimum, the studied period has been extended in the past and the data between AD 1620 and 1900 has been also included there. The length of the "moving window" epoch is taken to be 40 years. As in the "original" moving window procedure, the calendar years of the moving window centers are presented in the X-axis. The shifting time $t$, as a delay of the $^{10}Be$ in respect to the MLA, in years, is shown in the Y-axis. The cross-correlation shifting time step is 1 year. The same one is the time step between the adjacent moving window epochs. For each "moving" window epoch a linear cross-correlation procedure has been provided and a series of correlation coefficients $r$ for the different shifting $\Delta t$ has been found. The values of $r$ are presented in the pixels of the map in Fig. 6.

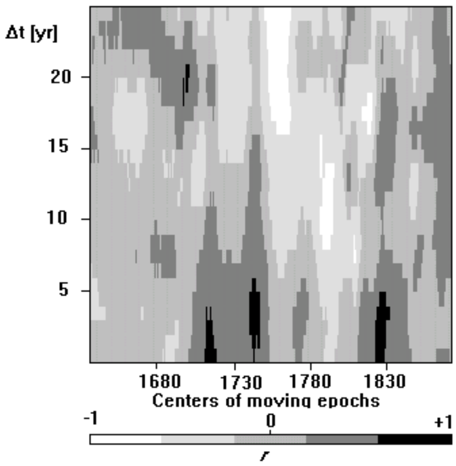


**Fig. 6.** The evolution of cross-correlation relationship between the "Greenland" $^{10}Be$ concentrations and annual MLA numbers.

There are three interesting epochs in which (1) the correlation coefficients between $^{10}Be$ concentrations and annual MLA number is more than $+0.6$ and (2) the phase shifting $\Delta t$ is 5 years or less. The first one is centered near to AD 1725 (the final phase of the Maunder minimum), the second one is near to AD 1740 and the third one is centered near to AD 1825 (the middle and final phase of the Dalton minimum). There is also moderate high values of $r$ (in the range of $+0.2$ to $+0.6$) and small shifting ($\Delta t < 5$ years) near to AD

1770. There are two epochs of strong anti-correlations near to AD 1690 (the deepest phase of the Maunder minimum), as well as at AD 1795 (the initial phase of the Dalton minimum). In both these epochs $r < -0.6$.

In our opinion, the final phase of the Maunder minimum, as well as the second part of the Dalton minimum are the epochs in 18th and 19th centuries, when significant parts of $^{10}Be$ could had been produced by powerful solar eruptive processes. Is this in contradiction to the "conventional" point of view for the very low solar activity levels during both epochs? Our preliminary answer is "no", but we will discuss this and the other results in details in Section 4.

The next step in our study is to compare the T-R spectrum of the MLA events and $^{10}Be$ concentrations for the epoch of the well established data about MLA, i.e. AD 1700-1900. The T-R spectrum of MLA series has been already presented in Fig. 4, while the respective one for $^{10}Be$ is shown in Fig.7 .

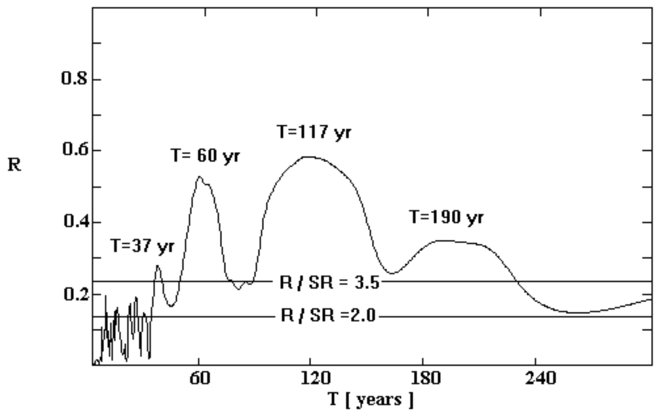


**Fig. 7.** The T-R spectrum of the "Greenland" $^{10}Be$ series (AD 1700-1900).

There are three important cycles at 60, 117 and 190 years, respectively, as well as one weaker cycle at 37 years. Under the level of $Rsigma(R)$=3.5 , but higher than 2.0, quasi-cyclic oscillations at 13.5, 22 and 25 years may be noted. The powerful quasi 60 yr cycle and somewhat quasi-bicenturial one exist both in the MLA and $^{10}Be$ series, while the main difference is related to the oscillation of $\approx$ 117 years in the second one, absent in the MLA series.

The last step in our analysis is the comparison of $\approx$ 60 yr cycle phases in both series. Relatively good coincidence between models of the phenomena is shown in Fig. 8. The mean $^{10}Be$ data delay of about $\approx$ 5 years during the studied time period is well visible. It is larger at the beginning of 18th century and slowly and monotonic decrease during the next 200 years. This

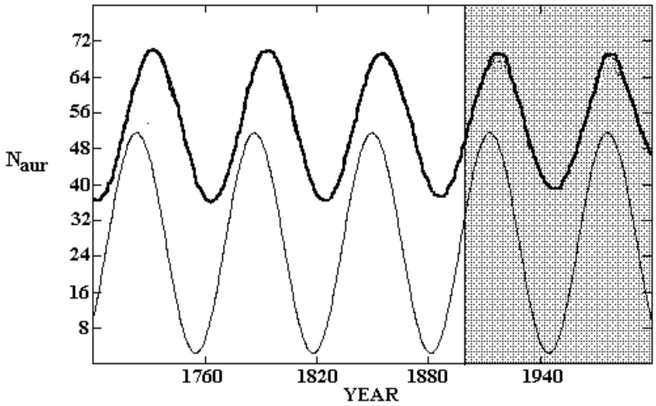


**Fig. 8.** Models of the quasi 60 yr cycles in the MLA (thick line, $T$=62.5 years) and $^{10}Be$ "Greenland" (bold line, $T$=60 years) series. The $^{10}Be$ data are multiplied by factor of 50. An extrapolation of both oscillations during the 20th century is shown as dark zone in the right.

effect is caused by the small differences of both oscillations - the established $^{10}Be$ cycle has 60 yr duration, while the MLA one is slightly longer (62.5 years). This difference is non-significant and most probably it is an effect of uncertainties in the used data sets. On other hand, as it has been mentioned above, there should also be an effect of the "resident time" between the solar activity forcing moments in the atmosphere, which indicator are the MLA events and the respective $^{10}Be$ accumulation on the Earth's surface.

That is why we may conclude that the coincidence between the corresponding 60 yr cycle extremums is enough established fact in this study. It is also needed to point out that the mean moments of all 60 yr cycle extremums, especially in the MLA series, are in very good coincidence with the reverse moments of the subcenturial ($\approx$ 60 years) climate oscillations (see Paper I). This is also valid for the extrapolated $\approx$ 60 yr oscillation tendencies during the 20th century (Fig. 8). The problem in this relationship, as well as the possible physical mechanisms of its origin, will be discussed in details in the next Paper III.

## 4 Discussion

We studied the "Greenland" $^{10}Be$ series using T-R method for first time in 2003 (Komitov et al., 2003). The large yield of the established there 66 yr cycle, as well as of the other "non-typical" for the overall sunspot activity cycles with duration of 50, 120 years, etc., was then noted. These "beryllium" cycles have been compared with their analogs in the tree ring widths, which are taken from the International Tree Rings Data Base. The possible solar origin of these oscillations and especially of the 66 yr one is discussed in this paper. However, not enough stable evidences for this suggestion were known by us on that stage. An alternative and most probable explanation was that all these cycles are caused by climatic effects over the $^{10}Be$ atoms deposition on the Earth's surface (Lal and Jull, 1992; Damon et al., 1997). In other words, the quasi 60 yr climatic oscillations (Schleissinger, 1993; Thompson, 1997) affect the $^{10}Be$ data and generate 60 yr $^{10}Be$ cycle.

In this study the existence of powerful quasi 60 yr cycle in the annual MLA number is evident. The MLA phenomena are products of the most powerful eruptive processes on the Sun, which affect the upper atmosphere and whose independence from the climate changes is out of doubt. It was also found that during the studied epoch (AD 1700-1900) both 60 yr cycles in the MLA events and the "Greenland" $^{10}Be$ concentrations have almost equal period (the difference is less than 5%). The moments of their extremums coincide very well with the reverse points of the corresponding climate 60 yr cycle, beginning with the end of Maunder minimum and the Little Ice Age in the end of 20th century (Fig. 8).

From the last fact a new point of view about the origin of the quasi-subcenturial oscillations could be suggested, i.e. the climate oscillations with subcenturial duration are caused by high-energetic eruptive processes on the Sun. These processes are also a primary sources of the MLA phenomena. Therefore, the physical processes forcing over the climate are very similar to the penetrating Earth's atmosphere GCR-flux with energy in the range of 10-1000 MeV or higher (Paper III).

Our results indicate also the possibility that a significant part of $^{10}Be$ atoms in Earth's atmosphere could originate in the most powerful solar corpuscular eruptions, probably CME events. The dynamics of MLA show that there should be a significant $\approx 60$ yr cycle in the frequency and the power of these solar events. However, there are not enough long observational data series for the CME events to test such hypothesis.

The used here MLA events data set ends on AD 1900. An extrapolation of the 60 yr cycle of these phenomena during the 20th century is given in Fig. 8. It seems realistic because the corresponding $^{10}Be$ 60 yr oscillations (the bold line) really follow their extrapolated scenario in 20th century up to AD 1985, the end of the "Greenland" series (Komitov and Kaftan, 2004). As it is shown in Fig. 8, the last (extrapolated) MLA maximum should be near to AD 1975 and the next predicted maximum should be about AD 2005-2007 within a downward tendency. Consequently, if our discourse is correct, a downward tendency after AD 1975 should be observed not for all solar indexes related to the solar eruptive activity and especially the coronal activity.

Indexes of the solar eruptive activity could be, for example, the radio-bursts in the metric range with frequency less than 100 MHz. They are considered as a good proxy of the CME activity (Duchlev, 2006). Regular complete observations of the Sun in the metric range have been performing after AD 1996. The analysis of the respective data series may be an object of a future study. However, in advance we may note that there is a sharp downward tendency of the monthly number of the radio-bursts of all types at $f$=29 MHz from AD 1979 up to AD 2008 (Upice station). As it is shown in Fig. 9, the 10-11 yr oscillations in these data seem weak expressed. In the same time, the downward trend in the overall activity could be better expressed by the downward phase of a cycle with duration in the range of 65-70 years. All these facts are in agreement with the T-R spectra of MLA series, where the 62.5 yr cycle the is dominant, while the 10-11 yr cycle is weak (Fig.4).

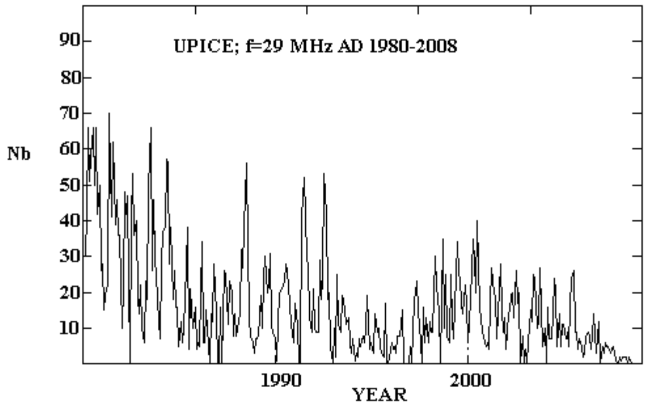


**Fig. 9.** The monthly number of radio-bursts of all types ($N_b$) at $f$=29 MHz (Upice, Czhech Republic; AD 1980-2008).

It is known that the solar corona phenomena don't follow very close the photosphere activity. This fact is already pointed by Duchlev (2001). He noted about ≈ 117 yr cycle in long-lived solar filaments, which is connected with the north-south asymmetry of the solar activity processes. It could be considered the $^{10}Be$ 120-130 yr cycle in both the "Greenland" and "Antarctic" series is a probable consequence of the solar corona phenomena. A cycle by duration of 11 Schwabe-Wolf's cycles (≈ 120 years) has been also established in Schove's series (Komitov, 1997). But are there some evidences for that a significant subcenturial oscillations could exist in the photospheric active phenomena?

As it has been already noted in Paper I, and according to our previous results (Komitov and Kaftan, 2003), there are statistically significant subcenturial cycle (50-70 years) in sunspot activity indexes. However, it is essentially weaker in respect to the dominant Schwabe-Wolf's cycle. For this reason the subcenturial oscillations are "damaged" in the overall sunspot activity dynamics. It is reasonable that these oscillations are typical manifestation only of separate type of sunspot groups, groups with complicate structure, largest size and visible by naked eye. Such sunspot groups could be a primary sources of the powerful eruptive events, including the coronal mass ejections (CME).

The naked eye visible giant sunspot group No. 798, observed on Sep 07, 2005 is shown in Fig. 10. This photo is downloaded from
*http : //www.xs4all.nl/ carlkop/auralert.html.*

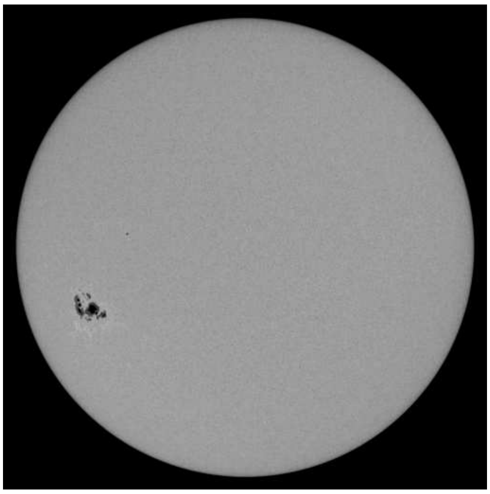

**Fig. 10.** The giant naked eye visible sunspot group No. 798 (Sep 07, 2005).

The group No. 798 was a source of extremely high geomagnetic activity, middle latitude auroras and X-ray flares (including alo X17 class). This sunspot group could be considered as a potential candidate of this class of sunspot activity for which the quasi 60 yr cycle can be an important feature. However, the common used sunspot indexes $R_I$ and $R_h$ are quantitative parameters of the total sunspot activity, but the time behavior of the specific types of sunspot groups is not taken into account there.

The existence of 54 and 65 yr cycle traces in the auroral activity was noted by D.J. Schove in 1950 (Schove, 1955). Unfortunately, this result was passed without attention or was forgoten by the researches during the next decades. We should feel sorrow for this, because these oscillations could turn out to be an important key for better understand of the Sun-climate relationship, as well as for the overall mechanism of climate changes. The continuation of this discourse will be presented in Paper III.

As it is shown in Fig. 6, there is a strong positive correlation between $^{10}Be$ production and MLA events during the most part of the Dalton minimum (1795-1830), as well as during the final phase of Maunder minimum (1640-1720). It is interesting that in both cases a slightly increasing of MLA events occurred and the corresponding number of MLA events is not very high. This is an indirect evidence for that during these epochs the solar eruptive phenomena has been relative rare, but essentially more powerful as in the other epochs. This important conclusion is in connection with the fact that now (May 2009) the Sun is in the beginning of a new supercenturial minimum (Badalyan et al, 2000; Komitov and Bonev, 2001; Miletsky, 2003; Komitov and Kaftan, 2003; Nagovitsin and Ogurtsov, 2003; Solanki et al., 2004; Bonev et al., 2004; Ogurtsov, 2005; Cliverd et al, 2006; Komitov, 2007). A discussion in this course, as well as about the possible expected climatic effects will be presented in the next Paper III.

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