DOI: 10.31401/WS.2020.proc.22

The Beech Tree Ring Widths, Solar-Climatic Relationships and Solar Dynamo Regime Changes

Komitov B. [1], Kaftan V. [2]

[1] Institute of Astronomy and NAO - Bulgarian Academy of Sciences
[2] Geophysical Center - Russian Academy of Sciences

Abstract.

In this study the results from analysis of annual ring widths *Dm* time series of two "very sensitive" to climate and solar-climate relationships long lived beech samples (age of 209 and 245 years respectively) are discussed. The both series are characterized by very good expressed 20-22 year oscillations, related to the solar magnetic Hale cycle. A good coincidence between the changes of *Dm* and the forcing or fading of solar magnetic cycle is found. The transition effects at the beginning and ending of the grand Dalton (1793-1833) and Gleissberg minima (1898-1933) are very clear visible in the annual tree ring width data for the one beech samples. Some of these effects are detected also in the second sample. The problem for the possible "lost" sunspot cycle at the end of 18th century is also discussed.

Introduction

The idea for investigations of solar activity in the past as well as the "Sun-climate" relationships on the base of tree ring widths measurements are suggested by the American astronomer Edward Douglass (1867-1962), the "father" of dendrochronology. He has provided the pioneer studies in this field on the base of long lived tree ring samples manly from the south-west part of USA [Frittz, 1975]. Few decades later the British scientist Derek Schove partly uses dendrochronological data for reconstruction of solar activity in the past (the so called "Schove's series") [*Schove*, 1955, 1983]. Recently, in 1970th extended study of solar-climatic relationships based on dendrochronological data from the west part of USA has been made. A relative new dendrochrinological studies, which are oriented to "Sun-climate" problematic has been published by Rasspopov et.al [2008].

However, in many cases there are significant uncertainties relating the tree ring widths data and their analysis. They are due to biological features of the wood samples growth. Participating in photosynthesis, the trees consume water and nutrient resources from the surrounding soil, along with a number of growing representatives of the flora - trees, shrubs, and grasses. The latter are competitors in the use of these resources. Therefore, the growth of a tree at its various stages depends, to a certain extent, on the growth rate of the surrounding plants. In this case, additional external factors, such as industrial or sanitary deforestation, windfall, storm erosion of the upper soil layer, the laying of forest roads near the test sample, etc. can play a role. Landscape features, such as the slope of the terrain and the petrochemical composition and physical properties of the soil, also affect the degree of uncertainty in the estimates of the influence of solar activity and climate on tree growth. Trees growing on negative landforms, e.g., in river floodplains, receive abundant water supply from the moisture-saturated soil. Their growth is too inert with respect to atmospheric climatic changes. The effect of precipitation in short-time scales for these cases may not be noticeable

Otherwise, when the tree grows on steep slopes in soils with a small accumulation of water, a more intense influence of solar and climatic factors on the growth of the tree can be expected. In the best such cases on the base of corresponding data it could found and analyzed some fine effects in solar-climatic relationships evolution and connected with the last one solar dynamo regime changes.

The tree rings widths time series investigation of a long lived (age 209±1 years) beech sample in aspect of "Sun-climate" and solar dynamo regime changes during the interval 18th-

21st centuries is the subject of this paper. Another long lived beech sample (age 245 ±5years) time series has been also used for some comparisons.

Data and methods

The both beech samples (*Fagus Silvatica*) has been obtained in Central Stara Planina (Balkan Mountain Range). The first one, labeled as Gurkovo-01 was logged in 1983 from a site on the south slope of Stara Planina (in Region of Stara Zagora) and ~800 m above sea level. It is 209 ±1 years old. The second sample Rositsa-01 was logged in 2011 in ~50 km NW from Gurkovo-01 on the north slope of Stara Planina (in Region of Gabrovo) and 1000 m above sea level. The age of this sample is 245±5 years.

These samples are used in a series of earlier our works, concerning the studies of solar-climatic relationships, based on dendrochronological data from Bulgaria. The measurement and preliminary data proceedings has been described in our previous works (see [*Komitov et al*., 2013] and cites therein).

Stara Planina is a significant climatic boundary. On the north side of mountain range where the Rositsa-01 site is, the main air transit comes predominantly directly from North Atlantic. Over South Bulgaria, the air transition from Mediterranean Sea (and connected with it Mediterranean cyclones) play also important role. During the 20th century a statistically significant 20-22-year cycle in variability of precipitations and temperatures instrumental series for the warm part of year (April-October) in ~70-75% of South Bulgaria territory has been detected [*Komitov*, 1986]. In contrary, in North Bulgaria the 20-22-year climatic cycle the last circumstance only for separate few meteorological stations is valid. The terrain of Rositsa-01 site is featured by significantly higher underground water resources as the Gurkovo-01 site. Taken also into account the above mentioned, related to climatic differences between North and South Bulgaria it could in advance to expect that Rositsa-01 tree rings width series is less sensitive to short – time oscillations like 20-22-year solar-climatic cycle as Gurkovo-01. The validity of this suggestion will be demonstrate below.

As is known the 10-11-year and 20-22 year solar cycles are basic phenomena for the solar dynamo theory [*Choudhuri*, 2007]. However, a statistical significant 11-year cycle signal in the beech samples time series not exist. This is related to the fact that the beech vegetation season is between April and October, where the 20-22-year, but not 11-year solar-climatic cycle is significant [*Komitov*, 1986]. That's why our study is focused mainly on the 20-22-year cycle amplitude and statistical significance variations in the both tree rings time series.

The time series analysis is based on T-R periodogram algorithm, which is described in few our previous papers (see [*Komitov,* 1997] and cites therein).

Results and analysis

The smoothed by 5 years tree rings width time series of both samples is shown on Fig.1.

One of the most impressive features in Gurkovo-01-time series (left panel) are the clear visible solar modulated quasi-cyclic oscillations by duration of ~20 years during the larger part of investigated period – since 1830 AD. The local minima of quasi-20-year oscillations of *Dm* correspond to minima of even numbered in the Zurich series sunspot cycles, while the *Dm* maxima occur predominantly near to odd Zurich sunspot maxima. This fact is in agreement with our earlier results, based on instrumental data for 20th century about tendency for drier and warmer "summer" half-year seasons (May-October) during the even numbered Schwabe-Wolf's sunspot minima and more wet and colder ones near to even numbered sunspot cycles maxima. The statistically significant negative coefficient of linear correlation r = -0.69 between "summer" half-year precipitation in Stara Zagora meteorological station (in Central South Bulgaria) and *Dm* of Gurkovo-01 beech sample tree widths series during the epoch (1926-1982 AD) supported this statement. On the other side the statistically significance of correlation coefficient between the mean "summer" half-year temperatures are even higher *r* = -0.71. Our analysis points out that leading factor for *Dm* changes is the temperature, while the relationship between precipitations and *Dm* is just effect of a strong correlation between the precipitations and temperature.

The second important feature in the left panel on Fig.1 is the serious drop of 20-22-year cycle amplitude during the epoch 1790-1830 AD, which corresponds to the solar grand Dalton minimum.

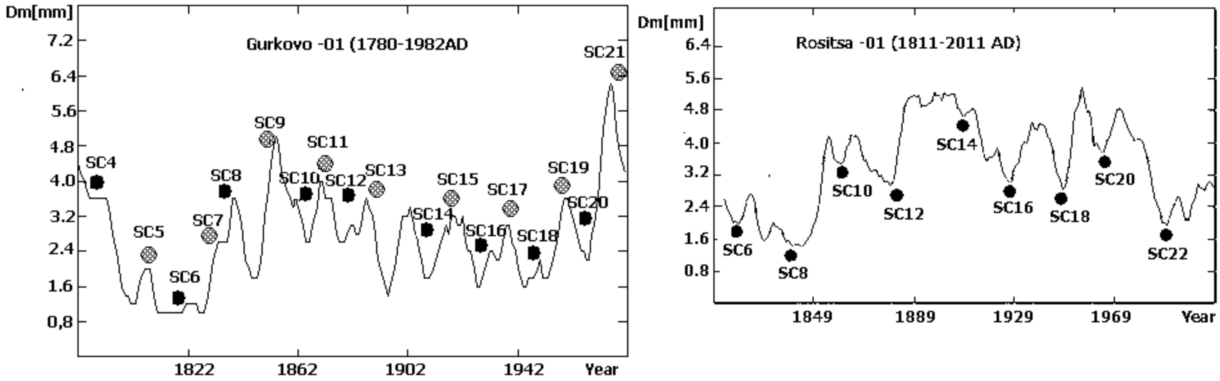

Fig.1. The smoothed 5-year beech annual ring widths series (left: Gurkovo-01; right Rositsa-01). The odd numbered Zurich sunspot cycles maxima are marked by gray spots, the even numbered ones –by black spots.

On the right panel of Fig.1 the smoothed by 5 years *Dm* time series of Rositsa-01 cycles is shown. There are weak 20-22-year oscillations. They are strongly dominated by quasi-periodic trend by duration of *T*=207 years (see Fig.2, right panel). The both minima of this bi-centurial "hyper-cycle" (also by solar origin [Rasspopov et al., 2008]) are during the Dalton minimum and the present epoch of low solar activity. In contrary, the bi-centurial oscillation in Gurkovo-01series is not visible. May be somewhat it is caused by the fact that this series is ended in 1982 AD, when the new long term solar minimum was not starts yet.

This comparison was useful by the fact that it demonstrates the significance of a large number of conditions, which are strongly necessary to taken into account for more precise analysis of "Sun-climate" relationships and interesting events in solar dynamo regime changes in the past. Gurkovo-01 is the essentially better for studying of the much shorter time scale effects due to the better manifestation of solar magnetic 22-year cycle effects

It has been established in our present study that the statistically significant quasi periodic oscillations in Gurkovo-01 time series by duration of 17, 21, 24, 46, 64 and 108-year are well detectable. All they have analogs in solar and geomagnetic activity, except the 46-year one, which origin is by our opinion unclear on this stage. The 64-year and 108-year are the most featured from all oscillations. Their peak correlation coefficients *R* are 0.515 and 0.649 respectively. There are also few weaker expressed cycles by duration of 12, 15, 27, 31 and 37 years. The 31-year cycle is equal of ~3 Schwabe-Wolf's sunspot cycles and could be also considered as resonance related to the 64-year cycle.

The Rositsa-01 T-R spectra contains statistically significant oscillations by durations of 38, 54, 84 and 207 years. The first one has analog in geomagnetic activity, while the other three – both in sunspots and sunspot activity. As it has been pointed out above the quasi decadal oscillations (~20-year) in Rositsa-01 are very weak and it is well shown also on the T-R correlogram. That's why the Rositsa-01 time series variations are a good indicator for the long-term solar dynamo changes and long solar–climate tendencies, but essentially less sensitive in short time scales.

A more detailed analysis for the 20-22-year oscillation changes in Gurkovo-01 series has been made by calculating of the integral power index S22 (see [Komitov, 1997] and cites therein). For the aims of present study, the possible interval of solar magnetic (Hale) cycle and corresponding to him climate and tree ring widths are choice to be 18 – 24 years. The time series of S22 is shown on Fig.2 (left panel), while the corresponding T-R spectra is shown on the right panel. The sharp fading of during the Dalton minimum was follows by epoch of significant higher mean level in the middle of 19th century. Approximately since 1860 AD a sharp downward tendency begins, which reach his minimum at ~ 1910-1912 AD. S22 is going up after that up to 1927-1928 AD. There is a shallow minimum near to 1940 AD. The epoch since 1940 and up to 1980 (Zurich solar cycles No 17-21) is featured by a general increasing of 20-22-year cycle amplitude. As it could to see in T-R correlogram (Fig.2., right) the 20-22-year cycle amplitude is modulated mainly by 64-year cycle and on second place by 107-year one. The third important cycle is by duration of ~32 years and most probable it is in resonance relationship with the 64-year one.

Quasi-60-year oscillations are detected in many phenomena in space and Earth climate. A ~62-year cycle has been obtained in middle latitude aurora (MLA) historical time series and "cosmogenic" isotope ^{10}Be abundances in Greenland continental ice core "Dye-3" [Komitov, 2009]. These facts lead to a very high probability to a hypothesis that the ~60-year cycle have a solar origin. The problem is very intriguing if taken into account that there is no significant manifestation of 5 or 6 sunspot cycles in sunspot indexes or they are weak if exist.

It needs especially note that a cyclic tendency of ~60-65-years follows from the study of Georgieva [2011] concerning the possible origin of the Schwabe-Wolf's cycle double peaked structure and the Gnevishev's gap between them. Based on sunspot activity data for 20th century she suggests that the both peaks of the ~11-year sunspot cycle are caused by two types of plasma transport in Sun's convective zone - advective and diffusive. Every one of these two gives its separate part in sunspot activity, which maxima are shifted meanly on 1.5 -2 years each from other. They correspond to the both main peaks of sunspot activity in Schwabe - Wolf's cycle. By our opinion there is an oscillation variable regime of the both types of plasma transport by length of ~ 6 Schwabe-Wolf's cycles, i.e. ~60-70 years. The order reverse of the both sunspot peaks ("advecive – diffusive" to "diffusive - advective" and on the contrary) occurs meanly on 3 sunspot cycles, i.e. approximately 30-35 years. Thus the ~60-65-year cycle could exist in solar dynamo without any significant manifestation in sunspot activity. On the other hand, these phenomena seems to play role in manifestations of solar flares, coronal mass ejections (CMS) as well as the solar wind parameters, geomagnetic storms and aurora activity.

We find that the detected the Gurkovo-01 sample series main local extrema of S22 are in good coincidence with the double types plasma transport scheme since the beginning of 20th century thereafter enough certain corresponding data from the sunspot observations are extracted. Due to this 60-year cycle there is an interleaving of 20-22-year cycles by high, moderate and weak cycle magnitude in the tree ring widths data, which is very well expressed in Gurkovo-01 beech sample. A 60-year cycle is detected in many Earth climate parameters, for example in the Northern hemisphere temperatures [Thompson, 1997]. Quasi-60-year variations has been detected in North Atlantic Oscillation behavior [Mazzarella and Scafetta, 2012].

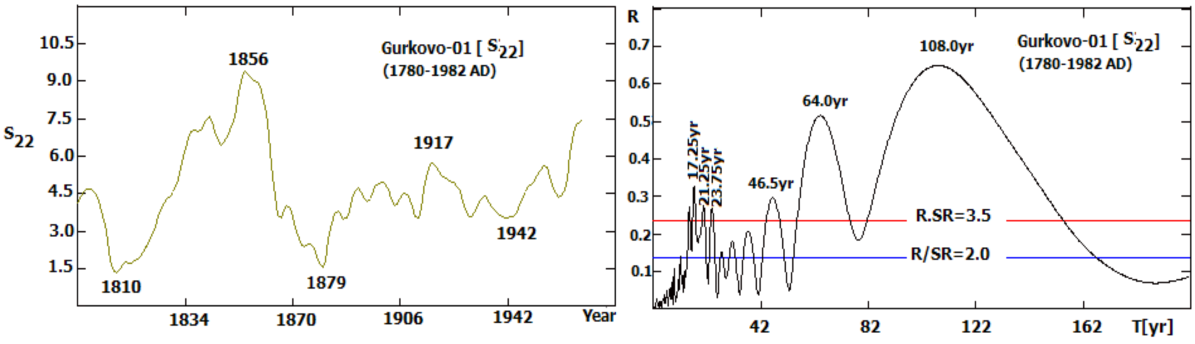

Fig.2 Left: The amplitude index S22 of Gurkovo-01 beech sample Dm-series. The moving window width is equal to 30 years; right: the corresponding T-R correlogram.

By our opinion the relative high sensitivity of Gurkovo-01 to the short scale solar activity oscillations like 20-22-year Hale cycle opens a possibility for more detailed study of the solar activity long term changes effects such as the transitions from high solar activity epochs to grand solar minima. In the Gurkovo-01 time series such phenomena could to observe in the end of 18th century – the transition epoch between sunspot cycle No 4 (SC4) and the weak next SC5. According almost all researchers it marks the beginning of grand Dalton minimum (1798-1825 AD). An exclusion of this "consensual" scenario is the suggestion for an additional weak and short "lost" sunspot cycle after SC4 [Usoskin et al, 2001]. This weak sunspot cycle SC4 should be started in 1793 AD and ends approximately in 1799/1800 AD. This hypothesis was very popular in 2000th, but finally it was not appropriated. However, all researchers agree that there was occurs an unusual sunspot activity behavior in 1790th, which indicates for a serious corruption of Schwabe Wolf's cycle during this time.

As it shown on Fig.1 the maximum of the even SC4 sunspot cycle coincided with an inflection on the graphics of *Dm*, while the smoothed moments of the remained even sunspot maxima correspond to *Dm* minima, i.e. local temperature maxima and precipitation minima. The "inflection" near to SC4 is very short and it was followed not by increasing but by an unexpected and even more strong and continuous decreasing.

The smoothed maximum of the next odd numbered SC5 corresponds to weak *Dm* maximum. Thus a serious destroying of 22-year solar cycle influence over tree ring widths growth is indicated during the last decade of 18th century. The "critical" moment is 1793 AD where by our opinion occurs the real start of Dalton minimum. The typical downward phase of sunspots in SC4 was break near to this calendar year, as it seems suddenly by some new phenomena, which forced the sunspot activity decreasing. Such phenomena potentially could be the Sun's tachocline region sinking. As it is shown on the same panel SC5 maximum corresponds to a weak, but clear visible *Dm* maximum. This fact indicates that there is no change in "*Dm*-22-year solar cycle phase" relationship between SC4 and SC5 maxima. Consequently, there is no indication for some additional Schwabe-Wolf's cycle at the beginning of Dalton minimum.

There is an indication about significant "surplus" *Dm* minimum near the end of 19th century (~ 1898/1899 AD). It is not in coincidence with even numbered sunspot cycle maximum, but with the minimum of the even SC14. This calendar moment is also estimated as a start of the grand Gleissberg sunspot minimum (1898-1923 AD).

Conclusions

Evidences about successful using of some tree ring data series for "Sun-climate" relationships and solar dynamo regime investigations on the base of presented their results and their analysis are given in this study. Such data series, obtained from long lived (age 200 year) could be a good indicator for reconstruction both of terrestrial and space climate in preinstrumental era.

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