Influence of solar activity cycles on cork growth – a hypothesis

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Abstract

Sunspot cycles may influence the growth of plants. The most important aspect of the solar variability is the 11 year cycle, and also 22 year magnetic cycle, observed in sunspot number variations, total solar irradiance variations and many other indices of solar activity. Examinations of tree rings seem to indicate that tree growth is affected in these cycles.

In this paper we investigated eventual relationship between the 11-year solar cycles and the growth ratio of cork from cork oaks (*Quercus Suber L.*) in Coruche, Portugal. We found possible signs of relationship demonstrating negative impact of high solar activity on cork growth. It appears that in period of lower amount of sunspots the cork (the bark of cork oak) is growing better than in periods with higher solar activity. The most influencing period is from January till September of year of growth. However, more data and more detailed study would be needed to confirm this hypothesis.

1. INTRODUCTION

It is generally known that the Sun is the main driver of the space weather (SW). An increasing number of studies indicates that variations in solar activity (SA) and SW have had a significant influence on Earth's climate (e.g. Friis-Christensen, 2001; Kristjánsson et al., 2002; Bebars, 2003; Marsh a Svensmark, 2003; Muscheler et al., 2003). However, the mechanisms responsible for a solar influence are still not completely known. Energy of the solar radiation governs a variety of processes in the Earth's atmosphere and at its surface.

Variations of total solar spectral irradiance (in average of ~0.1 % during a sunspot cycle) may inluence the Earth's climate. The mission PICARD, dedicated to the study of the solar forcing on the Earth's climate, and the physics of the Sun is described in (Tuillier et al., 2003). The mission consists of simultaneous measurements of the absolute total and spectral solar irradiance, the diameter and solar shape, and to carry out helioseismologic observations to probe the Sun's interior. Atmospheric transparency depends on changes of cloud properties due to cosmic ray (CR) ionisation (the latter being modulated by SA). Ion-induced aerosol particles (diameter range, 0.001-1.0 μm) can act as cloud condensation nuclei (Marsh and Svensmark, 2003). The Earth's climate depends directly on the reflectance (albedo). Therefore, Goode et al. (2003) investigated an indirect response of the SA on the climate by estimating the albedo using the ground-based observations of the reflected radiation (Big Bear Solar Observatory, USA) and the cloud conditions as well as the modelling. They found that both the observations and the simulations indicate that the albedo was significantly higher during 1994-1995 (SA minimum) than for the more recent period covering 1999-2001 (SA maximum).

Lockwood (2002) suggested that the open solar magnetic flux could be a good proxy of solar-induced climate change. Results from the Ulysses spacecraft allow us to quantify the open solar flux from observations of near-Earth interplanetary space and to study its long-term variations using the homogeneous record of geomagnetic activity Long-term evolution of this magnetic structures can cause variations of the total solar irradiance. Sharma (2002) calculated variations in SA during last 200000 years using estimated changes in ^{10}Be production rate and the geomagnetic field intensity. Makarov et al. (2002) studied relation between the long-term variations of the polar magnetic flux on the Sun and the Earth's climate and proposed the area of unipolar magnetic field of the Sun in high heliographic latitudes as a new index of the solar magnetic activity.

From this brief overview follows that the sunspot cycles may even influence the growth of plants. The most important aspect of the solar variability is the 11 year cycle, and also 22 year magnetic cycle, observed in sunspot number variations. Examinations of tree rings seem to indicate that tree growth is affected in these cycles The solar cycle has already been observed in terrestrial records, such as the nuclear activity variations of cosmogenic 14C from tree rings and 10Be in ice sample of polar caps, by sophisticated and high cost methods. By more simple methods, chronologies of tree ring width index began to be used as possible record of the solar activity variations in the past (e.g. Ogurtsov et al., 2002, Rigozo et al., 2002). In different locations of the world an influence of the 11 year-old solar cycle was observed in tree growth rings. It is well evidenced, that the thickness of tree ring depends on the level of the solar activity. Natural records, e.g. giant redwood (sequoia tree) ring data (or others), can be such way investigated to study the past global and regional climate, which was influenced by the solar radiative output variations, associated to solar activity, and vise versa. However, it could be interesting and useful to investigate the long-term evolution of other parameters of trees as well.

Therefore, in this paper we investigated eventual relationship between the 11-year solar cycles and the cork growth in Coruche, Portugal. The annual growth is supposed to have regular decreasing tendency (Fortes et al. 2004) which slope can be unequalled by weather specially rain and temperature.

2. DATA AND METHOD OF PROCESSING

Data on sunspot numbers (yearly averages) have been downloaded from the online catalogue of the sunspot index – SIDC (WS1). The cork samples were obtained from Coruche (39.05 N, -8.41W) Portugal. The cork was harvested in summer of 2004. A sample of size 20x20cm was taken from western part of the stem in height of 1.3m. Radial cut of the sample was polished with fine sand paper and cleaned with pressurized air. The polished surface was scanned with HP ScanJet 4850 with resolution of 1200 dpi. The obtained images were used to evaluate annual growth of cork. Harvested cork has age of 10 years; the previous harvest was done in 1994. For measurement of annual ring width we use software developed in University of Evora. This software works with bitmap files and requires input of dots per inch resolution. Human evaluator is than asked to mark cross-sectional line through which the annual rings are going to be measured. After at the end of annual ring among the cross-sectional line small perpendicular line is marked. This perpendicular line marks end (beginning) of vegetation period. Afterwards the software counts distances between crossings of the lines and save the values to database.

As already noticed in other works (Caritat et al. 1996, Fortes et al. 2004) the delineation of individual annual rings may be tricky. In older cork the autumn cork is more dense therefore darker. However this rule cannot be verified in younger cork where often the annual rings are brighter or even invisible. Therefore in described software, the evaluator is asked after the delineation to estimate the visibility of annual rings. Four grades are possible to attribute : VG – Very Good, when the evaluator is completely sure with all annual rings position, G – Good, when most of the rings are visible but not all of them, VB – Very Bad, is used when there is no certainty about the annual rings, and B – Bad, is attributed to the rest situations. In this work we present data from 6 samples which were marked as very good.

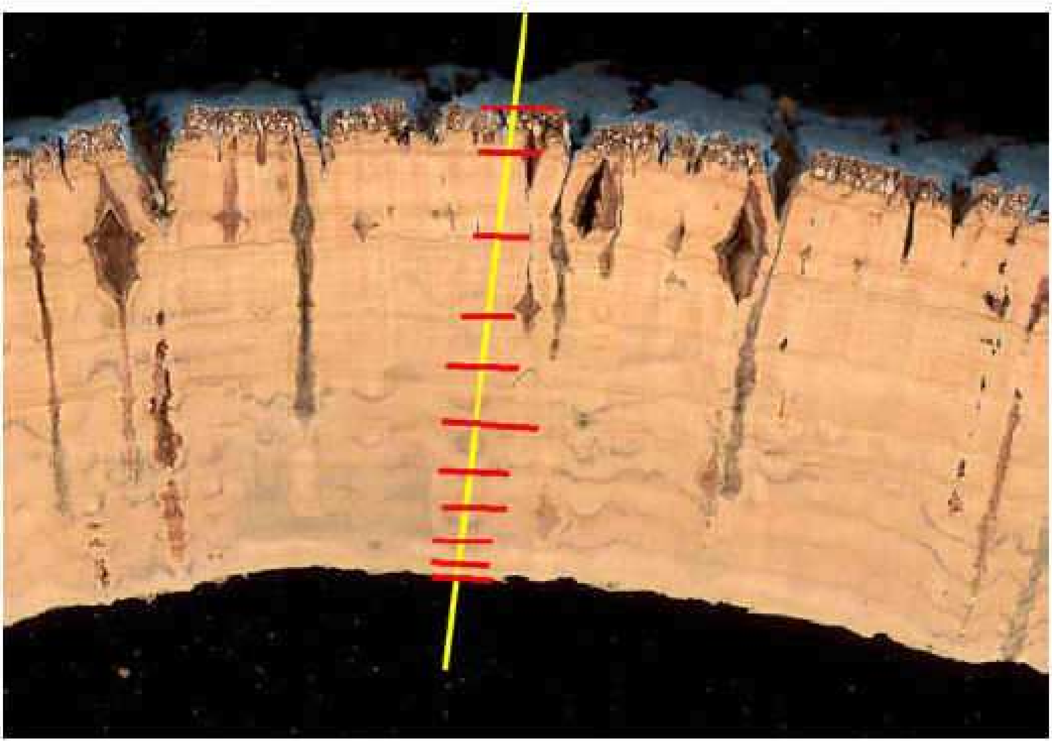

Figure 1 Marks of annual rings among cross-sectional line through cork sample.

3. SOLAR CYCLES AND CORK GROWTH

Annual growth of cork is influenced by set of factors mostly by: time since last debark (Fortes et al. 2004), temperature and rain (Caritat et al. 1996). Fortes et al. states that the cork growth is higher in the first years after debark than continuously decreasing until reaching its common form. Caritat et al. in 1996 recognises this fact however the decreasing tendency is disregarded in following analyses. It is due to the short time series (14 years) when comparing to other dendrochronological studies. In other works Ruohomäki et al 2000 and also in Selas et al 2004 it is demonstrated relation between moth pest species outbreaks and solar cycles. Both groups of authors came to the conclusion that the solar cycles might influence tree health status through assimilation redistribution. The main impact is not due to differences in solar irradiance but due to the UV – B irradiance which is higher in the periods of minima of solar cycle. The authors were observing herbivore insect's population outbreaks and they found that these outbreaks quite well correlate with solar cycle minims. The explanation would be that the tree during minima is under higher UV-B irradiation thus having to invest its energy and assimilates to protection against this radiation. More specifically they speak about polyphenolic protective substances. Production of these substances then weakens the tree and so it is more vulnerable to the herbivore insects which can then achieve population outbreak.

We present in this work a comparison between cork annual growth and solar cycles. The evolution of cork growth is shown in Figure 2. It is possible to observe in Figure 2 that the variation among different trees is quite small and that all are following sort of equal shape. It can be concluded therefore that there is external factor mostly influencing the shape of the line. Similarly to other author it can be observed the decreasing tendency and also irregularities in the form of the line (local maxima, minima). In Figure 3 it is demonstrated the overlay of cork growth and solar activity in individual years from 1994 to 2004. From this figure one can observe possible influence and relationship between solar activity and cork growth. If we would suppose, following the Ruohomäki et al 2000 and also in Selas et al 2004 we would expect that the solar maxima enhance the growth of cork because the tree would be less busy with production of protective polyphenolic substances. This hypothesis could be potentially seen in year 2001 when a local maximum in growth of cork occurs. However the solar activity maximum is in 2000 so it would not correlate perfectly. On the other hand the solar minimum (e.g. the negative impact on growth) is in years 1996 -1997 where no decrease in cork growth is observed. More likely it is observed the opposite (the growth maximum).

More detailed study of solar activity shows (in Figure 4) that there is in 2001 sort of local minima. This local minima is not visible in annual averages but it can have crucial effect on cork growth which is only produced only in certain part of year. Caritat et al 1996 found that cork growth is mostly influenced by precipitation accumulated from November of previous year till September of the year of growth.

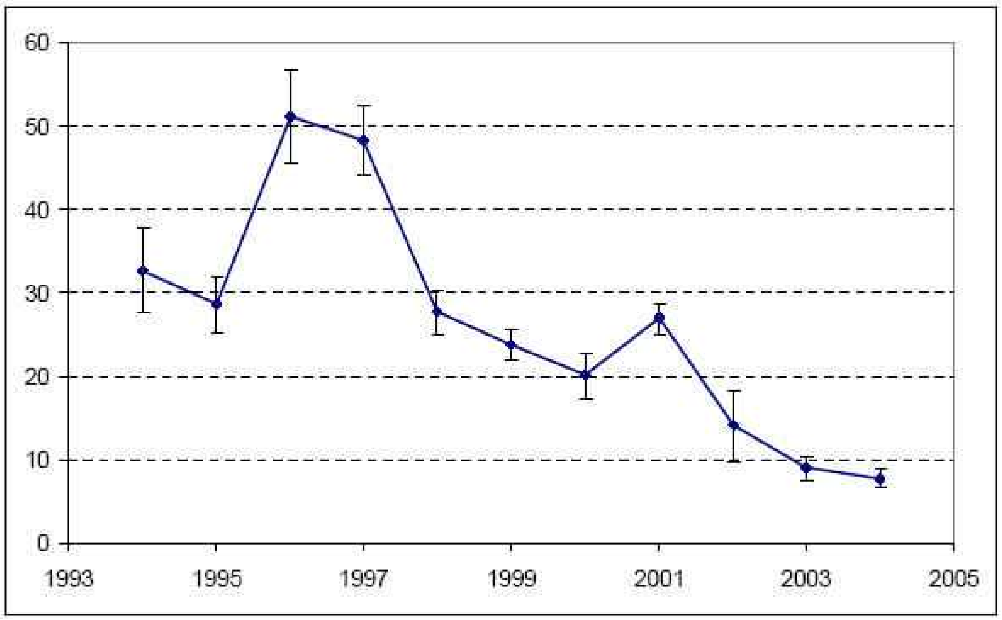

Figure 2. Evolution of cork growth (in pixels, 1 pixel = 0.1 mm) in the period 1994 – 2004 (sum of annual ring widths from 6 samples).

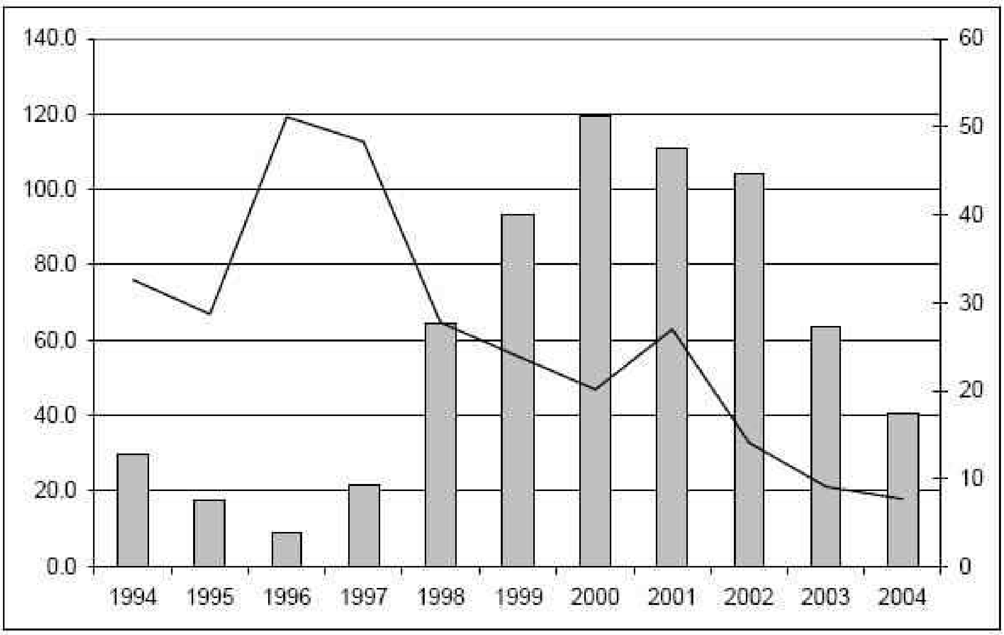

Figure 3 Overlay of solar cycle annual mean values and mean annual growth of cork.

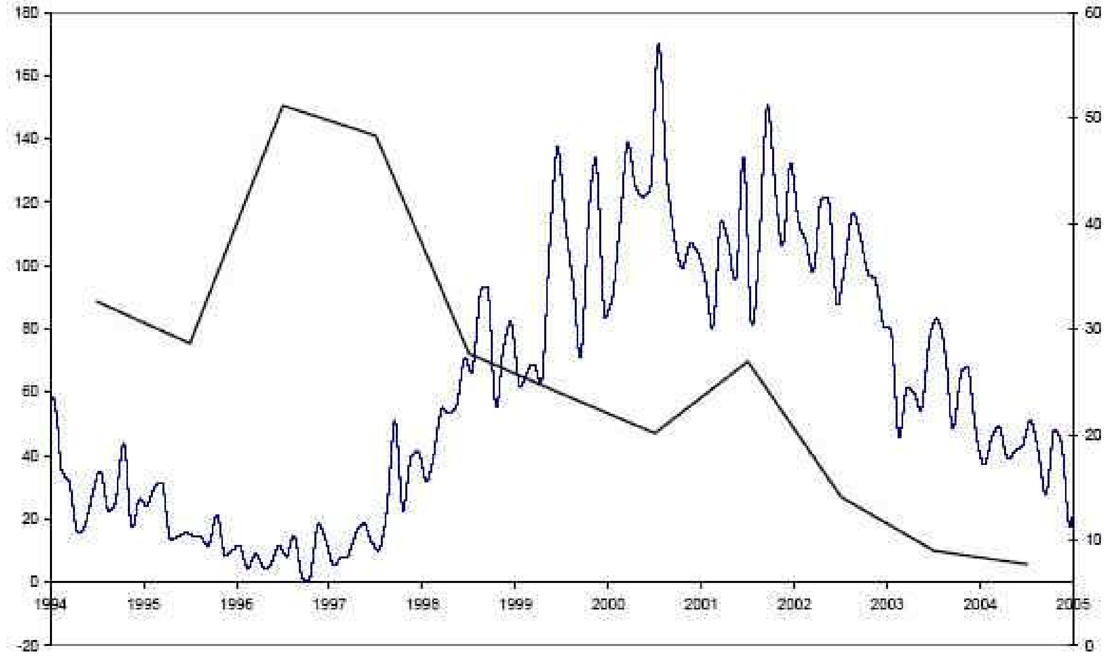

Figure 4 Overlay of the sunspot number monthly mean values (left scale) and the mean annual growth of cork (right scale, in pixels, 1 pixel = 0.1 mm).

We investigated potential influence of solar activity to cork growth through statistical regression. For a simplicity we omit all the potential factors (precipitation, temperature, dynamics of cork growth due to year of debark) and only evaluate the hypothetical impact of solar activity. We used monthly values of SA, summed them in different periods starting with September of previous year length 12 months, 11 months etc.. then starting with October previous year length 11 months, 10 months etc. . The results are shown in Table 1. It is possible to see that the R-square does not explain more than 50% of the data. However this fact is easy to explain due to previously mentioned simplification of data, e.g. solar activity is not the only factor influencing the growth obviously. However it can be observed that the correlation is existing and it can be described as significant. The best correlation was found between the period of September of previous year till December of previous year. This fact would have quite difficult explanation and probably it is only due to the low amount of data. More logical would be the period Sept – March or Jan – Sept when the cork growth is mostly occurring.

Table 1. Correlation between solar activity and cork growth.

Period R	R	R-square	signifi-cance
Sept – Dec	–0.731	0.534	0.011
Sept – Jan	–0.717	0.515	0.013
Sept – Feb	–0.711	0.506	0.014
Sept – Mar	–0.699	0.489	0.017
Jan – Sept	–0.687	0.473	0.019

In all cases it was found that the regression between solar activity and cork growth has negative shape. By other words higher solar activity has negative influence on growth of cork in present year.

4. CONCLUSIONS AND FUTURE WORK

We present in this work a study about hypothetical influence of solar activity on cork annual growth. It would be difficult at this moment to extrapolate our conclusions and more data and study are needed. For future it would be required to also examine the data on climate, specially precipitation and temperature and exclude influence of chronological trends in growth (decreasing tendency). In this work we omit these values however we were able to find correlation between solar activity and growth. The growth of cork in our study material illustrates to be negatively influenced by high solar irradiation. The most influencing period considered to be logical for cork growth is from January till September of year of growth. The annual solar activity values can delude some important values for growth.

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REFERENCES

Bebars, E.A.: 2003, in *Proceedings 'Solar variability as an input to the Earth's environment', International Solar Cycle Studies (ISCS) Symposium*, ESA SP-535, ed. A. Wilson, 347

Caritat A, Molinas M, Gutierrez E.: 1996, *Forest Ecol Manag*., 86 113-120.

Fortes MA, Rosa ME & Pereira HA: 2004, Cortiça., Editora IST Press, Lisbon

Friis-Christensen, E.: 2001, in *Proceedings of the NATO Advanced Study Institute on 'Space Storms and Space Weather Hazards'*, ed. I.A. Daglis, Kluwer Academic Publishers, 231

Goode, P. R., Pallé, E., Yurchyshyn, V., Qiu, J., Hickey, J., Rodriguez, P. Montañés, Chu, M.-C., Kolbe, E., Brown, C. T., Koonin, S. E.: 2003, *Journal of the Korean Astronomical Society*, 36, 83

Kristjánsson, J. E., Staple, A., Kristiansen, J., Kaas, E.: 2002, *Geophys. Res. Letters*, 29, 22

Lockwood, M.: 2002, in *Proceedings of the SOHO 11 Symposium on 'From Solar Min to Max: Half a Solar Cycle with SOHO'*, ESA SP-508, ed. A. Wilson, 507

Makarov, V. I., Tlatov, A. G., Callebaut, D. K., Obridko, V. N.: 2002, in *Proceedings of the Second Solar Cycle and Space Weather Euroconference*, ESA SP-477, ed. Huguette Sawaya-Lacoste, 563

Marsh, N. a Svensmark, H.: 2003, *Space Sci. Rev.*, 107, 317

Muscheler, R., Beer, J., Kromer, B.: 2003, in *Proceedings 'Solar variability as an input to the Earth's environment', International Solar Cycle Studies (ISCS) Symposium*, ESA SP-535, ed. A. Wilson, 305

Ogurtsov, M. G., Kocharov, G. E., Lindholm, M., Meriläinen, J., Eronen, M., Nagovitsyn, Yu. A.: 2002, *Solar Phys.*, 205, 403

Ruohomäki, K., Tanhhuanpää, M., Ayres, M., P., Kaitaniemi, P., Tammaru, T., Haukioja, E.: 2000, *Popul. Ecol.*, 42, 211

Rigozo, N. R., Nordemann, D. J. R., Echer, E., Zanandrea, A., Gonzalez, W. D.: 2002, *Adv. Space Res.*, 29, 1985

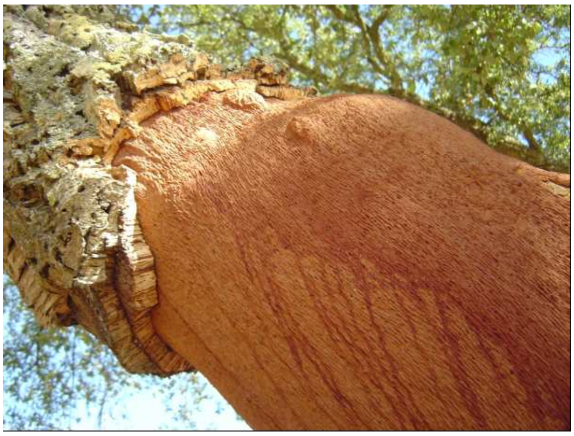
Selas, V., Hogstad, O., Kobro, S., Rafoss, T.: 2004, in. *Proc. R. Soc. Lond. B*, 271, 1897

Sharma, M.: 2002, *Earth and Planetary Science Letters*, 199, 459

Thuillier, G., Joukoff, A., Schmutz, W.: 2003, in *Proceedings 'Solar variability as an input to the Earth's environment', International Solar Cycle Studies (ISCS) Symposium*, ESA SP-535, ed. A. Wilson, 251

WS1: SIDC-team, World Data Center for the Sunspot Index, Royal Observatory of Belgium, *Monthly Report on the International Sunspot Number*, online catalogue of the sunspot index: http://www.sidc.oma.be/sunspot-data/

Cork oak (Quercus Suber L.) in Portugal.



Cork oak stem after cork harvest (photos: I. Dorotovič).

Cork oak stem after cork sample cutting (photo: P. Surový).