Adv. Geosci., 13, 25–29, 2007
www.adv-geosci.net/13/25/2007/

Advances in Geosciences

On periodicities in long term climatic variations near 68° N, 30° E

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Received: 30 August 2006 – Revised: 5 March 2007 – Accepted: 17 July 2007 – Published: 7 August 2007

Abstract. It is generally believed that the low-frequency variability of climatic parameters seems to be connected to solar cycles. The principal periodicities are: 11-year (Schwabe), 22-year (Hale), 33-year (Bruckner) and 80–100-year (Gleissberg) cycles. The main heliophysical factors acting on climate, the biosphere and the atmosphere are solar irradiance, the intensity of solar and galactic cosmic rays (relativistic charged particles with energies >500 MeV) changing the cloud cover of the atmosphere, and UV-B-radiation. The 11-year and 80–90-year solar cycles are apparent in solar radiation and galactic cosmic ray trends. At the same time the bidecadal Hale cycle, related to a reversal of the main solar magnetic field direction is practically absent in either solar radiation or galactic cosmic ray variations. Besides, nobody can identify any physical mechanisms by which a reversal in the solar magnetic field direction could influence climate. However, the 22-year cycle has been identified in rather many regional climatic (droughts, rainfall, tree growth near 68° N, 30° E) and temperature records all over the world. We discuss here three possible cause of the bidecadal periodicity in climatic records, one of which is associated with a variation of stardust flux inside the Solar System. The most recent observations by the DUST experiment on board the Ulysses spacecraft have shown that the solar magnetic field lost its protective power during the last change of its polarity (the most recent solar maximum), so that the stardust level inside of the Solar System has been enhanced by a factor of three. It is possible that the periodic increases of stardust in the Solar System may influence the amount of extraterrestrial material that falls to the Earth and consequently act on the Earth's atmosphere and climate through alteration of atmospheric transparency and albedo. This material (interstellar dust and/or cometary matter) may also provide nucleation sites and thereby influence precipitation.

1 Introduction

The role of solar activity in climate and environmental changes is now a subject of considerable discussion. The last two decades of research in solar physics, geophysics and climatology had led us to realize that:

1. Man-made influences on the environment are superposed upon a number of natural factors influencing the climate, atmosphere and biosphere of the Earth (Priem, 1997; Singer, 1999; Soon and Baliunas, 2003).
2. The main heliophysical factors acting on climate, the biosphere and the state of the atmosphere are solar irradiance (Reid, 1991; Lean et al., 1995; Douglass and Clader, 2002), the intensity of solar and galactic cosmic rays changing the cloud cover of the atmosphere (Tinsley et al., 1989; Shumilov et al., 1996; Svensmark and Friis-Christensen, 1997; Palle and Butler, 2001; Carslaw et al., 2002; Kasatkina and Shumilov, 2005), and UVB-radiation (Haigh et al., 1996).
3. The heliophysical factors demonstrate a cyclic character, identified in a large number of temperature and proxy records, as 11-year (Schwabe), 22-year (Hale) and 80–90 year (Gleissberg) sunspot cycles (King, 1975; Mann and Park, 1994; Stocker, 1994; Plaut et al., 1995; Molinari et al., 1997; Neff et al., 2001; Roig et al., 2001; Douglass and Clader, 2002; Rigozo et al., 2002; Gleisner and Thejll, 2003; Gusev et al., 2004).

The 11-year and 80–90-year solar cycles are apparent in solar radiation and galactic cosmic ray trends (Tinsley et al., 1989; Lean et al., 1995; Svensmark and Friis-Christensen, 1997; McCracken et al., 2001). At the same time the bidecadal Hale cycle, related to a reversal of the overall solar magnetic field direction is practically absent in either solar radiation (Lean et al., 1995) or galactic cosmic ray variation (Webber and Lockwood, 1988); nor could we identify any

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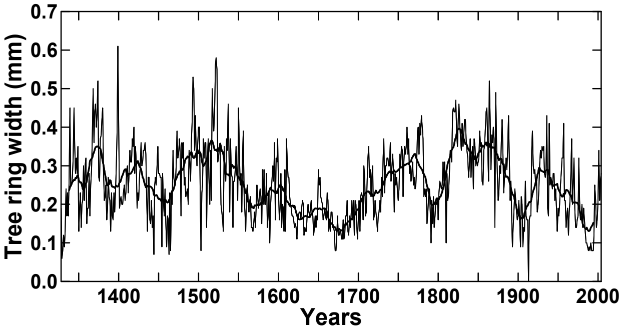

Fig. 1. The juniper (*Juniperus Sibirica Burgsd*) tree-ring chronology with 20-year running mean from the Kola Peninsula (67.77° N, 36.52° E), 1328–2004.

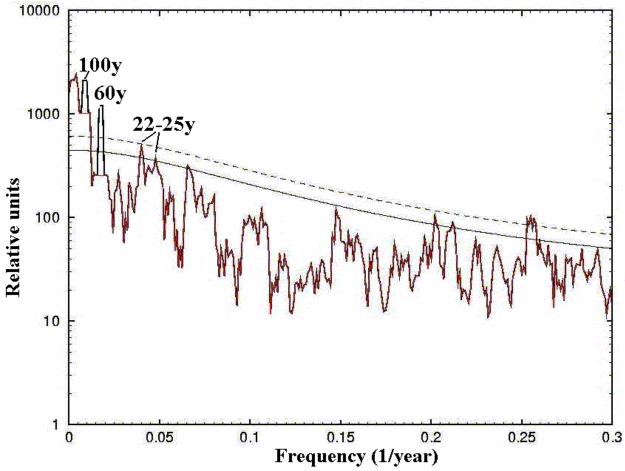

Fig. 2. MTM-spectrum of juniper tree-ring chronology (from Fig. 1). Strong periodicities are shown (in years, y). The lower (solid) and upper (dashed) lines represent 90% and 99% confidence limits.

physical mechanisms by which a reversal in solar magnetic field could influence the Earth's climate. However, the 22-year cycle has been identified in rather many regional climatic records worldwide (droughts, rainfalls, tree growth) (King, 1975; Cook et al., 1997; Gusev et al., 2004; Kasatkina et al., 2006). The 80–90-year solar cycle is less commonly preserved in climatic records (Stocker, 1994). The 33-year (Bruckner) solar cycle, the physical nature of which currently remains unknown, has only been identified in a limited number of regions: Northern Finland (Stocker, 1994), Tasmania (Cook et al., 1995), Chile (Roig et al., 2001), Mexico (Mendoza et al., 2001), and North America (Scuderi, 1993; Dean et al., 2002).

In this paper, we discuss the evidence for and some possible causes of bidecadal periodicity in climatic records in Finnish Lapland and the Kola peninsula, near 68° N, 30° E.

2 Data and method

For this analysis we used tree-ring and temperature records collected in different parts of Europe and North West Russia (about 50 records including 14 own tree-ring series). Tree-ring data (*Pinus sylvestris*; *Juniperus Sibirica Burgsd*) were sampled in Northern Lapland (40 km from Sodankyla; 67°22′ N, 26°38′ E; 2 series) and Kola Peninsula (67°33′–68°36′ N; 31°45′–34°58′ E; 12 series). The samples were cross-dated and ring widths were measured using standard dendrochronological techniques and COFECHA (Holmes, 1983) and ARSTAN (Cook and Kariukstis, 1990) programs. Most of the series begin in the 1700's; the largest juniper chronology begins in 1328.

3 Results and discussion

All data series were spectrally analyzed with the help of a multi-taped method (MTM) (Thomson, 1982; Dettinger et al., 1995) in order to search for solar activity signals. Spectral analysis of 46 tree-ring and temperature records taken from North Atlantic/Europe region revealed a significant peak around ∼22-years appearing almost in all records. Some examples are shown in Figs. 1–4. Figure 1 illustrates the juniper chronology for the Kola Peninsula covering the 676-year period from 1328 to 2004. Some of the juniper trees studied were rather old (300–400 years) with the oldest two reaching ages of 556 and 535 years meaning that they start growing in 1328 and 1350, respectively. Two millennia-long tree-ring width chronologies were constructed from juniper in the western Tien Shan (Esper et al., 2003). However, the juniper chronology is the longest chronology that has been constructed for the Kola Peninsula up to the present date. From Fig. 1 it becomes obvious that the juniper chronology contains a lot of low-frequency components. Figure 2 shows the MTM spectrum of the juniper chronology. It is curious that the 11-year solar cycle does not appear in the spectrum. The 20–22 year periodicity is, however, clearly present in the juniper chronology, at the 99% confidence level (Fig. 2).

Spectral analysis of the data revealed significant (close to 90% level or higher) peaks at around 4–7, 9–15, 20–25, 33, 60, and 80–100-years in the Kola and Lapland series (see Fig. 3). Peaks between 4 and 7-years may be related to the North Atlantic Oscillation (NAO) (Mokhov et al., 2000) with other peaks corresponding to solar cycles.

It has been observed that the 11-year periodicity is not always present in climatic records, and where the signal is apparent it is often seen at lower amplitudes than those of the 22-year cycle (D'Arrigo and Jacoby, 1992; Molinari et al., 1997; White et al., 1997). Moreover, in some regions solar forcing may be masked by local climate effects. The most significant differences in regional climatic variability were observed for the last 30–40 years in the Arctic where

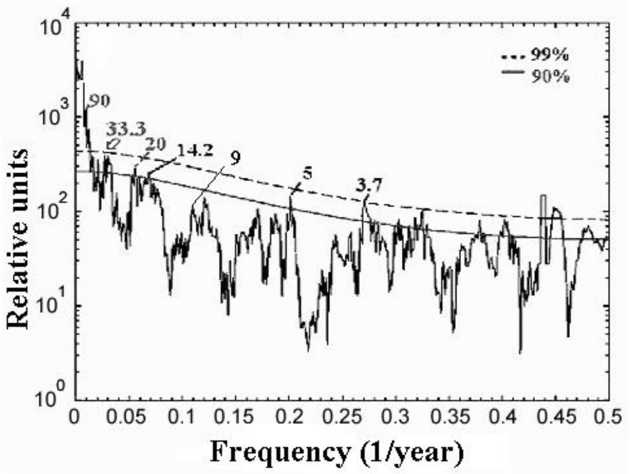

Fig. 3. The same as in Fig. 2, but for Northern Finland, Luosto (67° N, 27° E), 1635-1998.

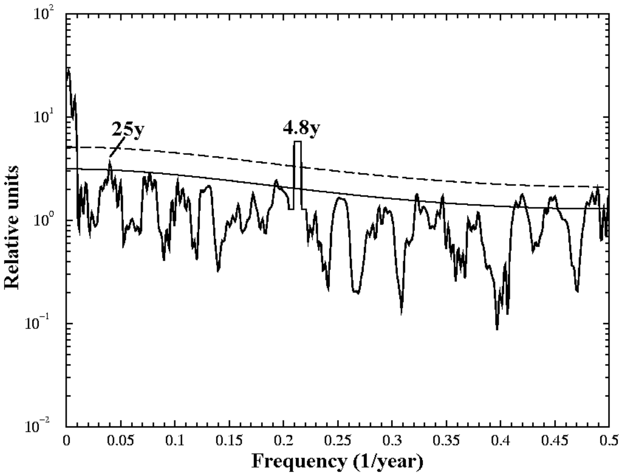

Fig. 4. The same as in Fig. 2, but for St.-Petersburg temperature (60.0° N, 30.3° E), 1752-2002.

the mean annual air temperature departures differ not only with respect to their values, but as well in sign (Kahl et al., 1993; Overpeck et al., 1997; Werner et al., 2000). It was shown that external forcing of the atmosphere and climate is enhanced in spatially-localized atmospheric patterns and/or so-called “climatic attractors” (zones with contrasting atmospheric states) (Shuleikin, 1942; Smirnov, 1984; Hurrel, 1995; Wallace et al., 1995; Corti et al., 1999). Recent results have demonstrated that in the North Atlantic/European sector solar forcing on the climate is localized approximately along the coastline of the Atlantic ocean (Thejll, 2001; Kasatkina et al., 2006).

As noted earlier, the periodicities of 11-year and 80–90 year solar cycles were identified in variations of solar irradiance and galactic cosmic rays. These periods are also evident in climatic variations. There are several reasons to consider the 33-year cycle observed in the Kola and Lapland series to be of solar origin. It has been discovered in variations of magnetic index (Ap) as well as of sunspots, although it is very unstable (Gonzalez et al., 1993). This period seems to be explained by the Sun’s oscillation about the center of mass of the solar system (Landscheidt, 1999). As for the 22-year solar cycle, although it is perceivable in climatic records, knowledge of any physical mechanism by which a reversal in the solar magnetic field could influence climate is still missing.

There are several possible interpretations of the phenomena observed:

1. Parametric resonance. In this case the 22-year peak may be connected to the non-linear response of the climatic dynamical system on the weak solar signal (doubling of the 11-year solar cycle) (Haken, 2004). This mechanism was discussed in some papers (Shuleikin, 1942; Smirnov, 1984; Hurrel, 1995; Wallace et al., 1995; Corti et al., 1999; Kasatkina et al., 2006).

2. Bidecadal variations of galactic cosmic ray (GCR) intensity (Ogurtsov et al., 2003). Ogurtsov et al. (2003) argued that the integrated GCR flux is doubled during solar cycles with positive polarity (magnetic field directed away from the Sun). It is true that the integrated GCR flux during negative solar cycles would be somewhat lower (Webber and Lockwood, 1988). But taking into account that the amplitude of the 11-year GCR variation is equal to about 10% at the ground (Tinsley et al., 1989), some part of this value would hardly influence climate considerably through variations in additional cloudiness. Besides, the effect is observed mainly at high latitudes according to Ogurtsov et al. (2003). Experimental results do not confirm this suggestion (Cook et al., 1997; Gusev et al., 2004; Kasatkina et al., 2006) (see Fig. 4). Figure 4 shows the MTM spectrum of temperature at the middle-to-high latitude station of St.-Petersburg (60° N). The 25-year periodicity is clearly present in this spectrum, above the 90% confidence level (Fig. 4).

3. Variation of stardust flux inside the Solar System. The Sun’s magnetic field protects the inner solar system from the interstellar dust penetration, and such dust grains (radius greater than 0.4 μm) may be focused in the plane of the ecliptic or diverted from the plane depending on its polarity, which changes every 11 years (Zank and Frisch, 1999; Frisch, 2000; Altobelli et al., 2003). The most recent observations made by the DUST experiment on board Ulysses have shown that this magnetic shield has lost its protective power during the recent solar maximum, and the stardust level inside the Solar System was trebled (Landgraf et al., 2003). According to model simulations, in the reversed configuration after the recent solar maximum (North negative,

South positive), the interstellar dust is even more effectively channelled towards the inner Solar System (Altobelli et al., 2003; Landgraf et al., 2003). Increases of stardust in the Solar System, if they penetrate the magnetopause, may influence the amount of extraterrestrial material that may rains down to Earth and consequently the Earth's atmosphere and climate (McCrea, 1975; McCay and Thomas, 1978; Zank and Frisch, 1999; Frisch, 2000; Landgraf et al., 2003). The increased amount of stardust material would change the gravity potential inside the Solar System. The increased gravity would affect the penetration of small comets into the Earth's atmosphere (Frank et al., 1986).

It is important to note that in a number of climate models variations with periods from 11 to 90 years are interpreted exclusively in terms of internal processes (ocean-atmosphere interaction, thermohaline circulation) without consideration of the role of solar forcing (Wohlleben and Weaverm, 1995; Latif, 1998).

4 Conclusions

Results of spectral analysis have allowed us to identify several solar activity cycles in tree-ring data collected in the Kola Peninsula and Finnish Lapland. The strong ∼22-year periodicity in climatic parameters may be related to the variation of stardust flux inside the Solar System caused by changes in the polarity of the main solar magnetic field.

Acknowledgements. This work was supported by grant from Russian Foundation for Basic Research (grant No. 05-06-97528), by the Program 'Biodiversity and dynamics of gene pool' of the Russian Academy and by the Regional Scientific Program of Murmansk region. The authors thank the referees for their useful comments.

Edited by: N. Crosby and M. Rycroft
Reviewed by: three anonymous referees

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