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Solar activity, global surface air temperature anomaly and Pacific Decadal Oscillation signals observed in urban outskirts tree ring records from Shenyang, China

Z.J. Chen [a,d], X.Y. He [a,*], W. Chen [a], X.M. Shao [b,c], Y. Sun [a], D.L. Tao [a]

[a] Institute of Applied Ecology, Chinese Academy of Sciences, 72 Wenhua Road Shenhe District, Shenyang 110016, China
[b] Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, Jia 11 Datun Road, Beijing 100101, China
[c] Institute of Tibetan Plateau Research, Chinese Academy of Sciences, 18 Shuangqing Road, Beijing 100085, China
[d] Graduate School, Chinese Academy of Sciences, Jia 19 Yuquan Road, Beijing 100039, China

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Abstract

A tree ring width chronology constructed from multiple samples taken from Chinese pine trees growing in outskirts of Shenyang city in Liaoning Province (China) was studied for the first time in relation to solar activity, global surface air temperature anomalies and the Pacific Decadal Oscillation. The work revealed an excellent response of urban tree growth to solar activity and global climate change, show as the time variation of the main periodicities in the Sun–Earth indices and its corresponding variation as recorded in tree rings, indicating that these urban Chinese pine are a suitable proxy for Sun–Earth system research in heavy industrial region, like Fuling Mausoleum that is located in Shenyang. Chinese pines show significant synchronous response to solar activity, in the periodic band 5–8 years, 10–16 years and 20–30 years. At the same time, the wave signal of tree growth was also affected, or even amplified by the combined effect of the PDO and GSATA with a short lag time, revealing 6, 13.2, 16.6 and 23.2 years oscillatory modes. At 20–30 years timescales, Chinese pines validated the strongest PDO and GSATA influence signal at 26 years and 20.8 years, respectively, and the 20.8 years fluctuation of GSATA may be the first cause of the tree ring 23.5 years periodic waves. Urban tree ring growth is also more sensitive to low periodicity, especially in the 2–5 years band width.

Keywords: Urban outskirts tree ring; Sunspot number; Pacific Decadal Oscillation; Global surface air temperature anomaly; Wavelet analysis

1. Introduction

Tree growth is influenced by simultaneous environmental factors, such as solar radiation, temperature, precipitation and soil water regimes etc. The width variation of yearly rings reflects the tree sensitivity and the influencing factors at the place where it grows. This is to say tree growth rings represent records of chronological series which are witnesses of the environment and climate that influenced their growth in the past (Fritts, 1976; Hughes et al., 1982; Wu et al., 1990), and it became necessary to indirectly monitor solar variations and other geophysical phenomena at a relatively long time scale into the past. The study of relations between tree rings and Sun–Earth climatic factors is becoming a common scientific task (Fritts, 1976; Hughes et al., 1982; Wu et al., 1990; Mann et al., 1998, 1999; Barber et al., 2000; Crowley, 2000; Rind, 2002; Briffa et al., 1998, 2004; Briffa and Osborn, 2002; Cook et al., 2004; Esper et al., 2002; D'Arrigo et al., 2005; IPCC, 2001; Zhou and Butler, 1998; Brito-Castillo et al., 2003). Most of these investigations based on the trees that are located in undisturbed regions and far away from human habitation. Urban outskirts trees have seldom caught researcher's attention due to their being relative high frequency disturbed by anthropogenic factors.

* Corresponding author. Tel.: +86 24 83970349; fax: +86 24 83970300.
E-mail address: woody7188@163.com (X.Y. He).

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In China, research on tree ring chronologies was started in 1930s with the study of climate records in samples from Beijing and northwest China (Wu et al., 1990). From then on, tree ring research has received wide attention in the Chinese scientific community to understand what physical mechanisms are responsible for the changing globe (Wu et al., 1990; Huang et al., 1993; Liu et al., 2004; Shao et al., 2004; Huang and Shao, 2005). But in length and breadth of land of Northeast China, especially in the typical heavy industry city, there has been rare or even no research work in this field. In this paper, in order to detect the responses of urban outskirts trees to solar activity (Sunspot Number-SSN), Pacific Decadal Oscillation (PDO) and Global Surface Air Temperature Anomaly (GSATA) in Shenyang city, Northeast China, a wavelet spectral study is made using indices based on accurately dated tree rings.

(1) Chinese pine (*Pinus tabulaeformis* Carr.), an endemic conifer species, is the most important dendrochronological resources for climate and environment reconstruction in China for it forms very distinct annual rings, allowing confident tree ring analysis and age determination. The species has a long life (about 300–500 years) and large ecological amplitude in northern China (Li et al., 1988).

(2) Solar activity as one driving force of global climate changes has been broadly studied (Eddy, 1976; Crowley, 2000; Rind, 2002; Friis-Christensen and Lassen, 1991; Haigh, 1996, 2001; Shindell et al., 2001; Bond et al., 2001; Yuan et al., 2004). The life at the surface of the Earth only exists because of the energy flux that our planet receives from the Sun. Solar radiation influences atmospheric and oceanic circulations, which also influence the biosphere (IPCC, 2001). One of the most important characteristics of solar variability is the sunspot variation in the Sun visible half, quantified through the sunspot number (Stuiver and Quay, 1980). Tree ring data have been used to study the climate in the past in relation to the solar activity (Hughes et al., 1982; Murphy, 1990; Dutilleul and Till, 1992; Kurths et al., 1993; Cook et al., 1997). The observed records of the sunspot number periodicities from tree rings of different trees from places with different climates, satellites and ^{10}Be concentration in polar ice show regular mean cycles close to 6, 11, 22, 52 and 90 years in different time scale. (Douglass, 1928; Wilson and Hudson, 1988; Beer et al., 1988; Frölich and Lean, 1998; Murphy, 1990; Kurths et al., 1993; Dutilleul and Till, 1992; Rigozo et al., 2002, 2003, 2004; Nordemann et al., 2005; Ogurtsov et al., 2002; Huang and Shao, 2005). These fluctuations have been present in centuries as well in decades scale (Kocharov et al., 1995). Other researchers have shown that there is a good correlation between the solar activity and tree growth rings (Mori, 1981; Damon et al., 1998; Rigozo et al., 2002, 2003, 2004; Nordemann et al., 2005; Ogurtsov et al., 2002; Huang and Shao, 2005), and an 11 years solar cycle was also found in growth ring series of trees with a short lag time (Mori, 1981).

(3) Broad scale global climate phenomena, such as the PDO and GSATA, affect diverse ecological processes such as tree growth. The PDO is a long-term ocean fluctuation that was first identified in sea surface temperature (SST) records of the Pacific Ocean (Mantua et al., 1997; Mantua and Hare, 2002), and has been described as a long-lived El Niño-like pattern of Pacific climate variability. Extremes in the PDO pattern are marked by most of the same Pacific climate changes caused by El Niño and La Niña. The strength and persistence of the variability in PDO affect rainfall, temperature and terrestrial ecology systems across broad regions of the globe. The PDO changes every 20–30 years and exerts a great effect on the climate over much of China (Mantua et al., 1997; Mantua and Hare, 2002; Guo et al., 2003). PDO variations are commonly monitored through indices constructed from SSTs and sea level pressures (Zhang et al., 1997; Mantua et al., 1997); its variations are often used as a measure of the amplitude of the El Niño and La Niña events (Mantua et al., 1997; Mantua and Hare, 2002). GSATA is derived from global annual-mean surface air temperature change recorded by the meteorological station network. Until the present time, temperature reconstruction by tree ring is an essential approach for the study of climate in the past (Fritts, 1976; Hughes et al., 1982; Wu et al., 1990; Briffa et al., 2004). Temperature of tree ring records comprise an independent archive of past earth surface temperature changes that is complementary to both the instrumental record and the climate proxies. Local temperature changes are often affected by fluctuations of temperature at the hemispherical or global scale (Briffa et al., 2004), so the research on regional climatic proxies has global significance.

2. Materials and methods

2.1. Sampling site

The master ring width chronology of Chinese pine in Shenyang city, Northeast China was used as the source of data to study the solar and climate change. Shenyang (Lat.: 41°11′51″–42°02′13″N; Long.: 122°25′09″–123°48′24″E) (Fig. 1), an important heavy industrial city of China, and capital of Liaoning province. The city lies in the center of Liaohe river plain. Its annual-mean temperature is 7 °C. And the annual-mean precipitation is 700.3 mm. Yellow Sea, Bohai Sea and Pacific Ocean are the dominant regions affecting the local climate change in this region. The original forest here was the temperate conifer and broad-leafed deciduous mixed forest, and the