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Sun–earth relationship inferred by tree growth rings in conifers from Severiano De Almeida, Southern Brazil

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Abstract

This study of Sun–Earth relationships is based on tree growth rings analysis of araucarias (*Araucaria angustifolia*) collected at Severiano de Almeida (RS) Brazil. A chronology of 359 years was obtained, and the classical method of spectral analysis by iterative regression and wavelet method was applied to find periodicities and trends contained in the tree growth. The analysis of the dendrochronological series indicates representative periods of solar activity of 11 (Schwabe cycle), 22 (Hale cycle), and 80 (Gleissberg cycle) years. The result shows the possible influence of the solar activity on tree growth in the last 350 years. Periods of 2–7 years were also found and could represent a response of the trees to local climatic conditions. Good agreement between the time series of tree growth rings and the 11 year solar cycle was found during the maximum solar activity periods.

Research highlights

► Study of Sun–Earth relationships based on tree growth rings analysis of araucarias were performed by using an iterative regression spectral analysis and wavelets. ► The result shows the possible influence of the solar activity on tree growth in the last 350 years. ► Short periods observed in tree growth ring series are due to local environmental conditions of El-Niño and La-Niña events.

Introduction

The environment at the surface of the Earth exists only because of the energy flux received from the Sun. Solar radiation influences atmospheric and oceanic circulations, which also influence the biosphere (National Research Council, 1994). Without solar radiation, photosynthesis stops. Solar radiation and high energy particles continuously collide into gases and plasmas in the atmosphere and magnetosphere, which protect life on Earth (Raisbeck and Yiou, 1984). Changes in the quantity of total solar energy input into the planet system are caused by three mechanisms:

1. Changes in Earth's orbital parameters, i.e., the obliquity of Earth's axis and the eccentricity of its orbit alter the incidence and distribution of the radiation incident on the planet (Eddy, 1980).

2. Processes inside the planet system, which regulate the quantity of energy received by the Earth (Lean et al., 1992).

3. Solar activity variations that modulate the energy emitted by the Sun (Wilson and Hudson, 1988).

The study of solar variations related to the energy flux is completely observational and very recent (about the past 40 years), which limits the understanding of their effects on climate and the possibility of long-term climatic predictions for the future. For these reasons, it is necessary to indirectly monitor solar variations and other geophysical phenomena at a more extensive scale into the past.

Tree growth rings, which represent records of chronological series, are witnesses of the environment and climate that affected their growth (Fritts, 1976). Several simultaneous environmental factors influence tree growth including: solar radiation, temperature, water precipitation and soil content, humidity, nutrients, neighborhood, pests, disease, etc. Depending on environmental conditions in which the tree and its species exist, some of these factors may prevail. Temperature, light and precipitation play an important role in regions with changing seasons and induce different growth rates caused by different cell size allowing direct visual recognition of the well-known tree growth rings. The thickness variation of yearly rings reflects the sensitivity of the tree to environmental factors at the location where it grows (Nordemann et al., 2005). Thus, precipitation and temperature fluctuations caused by El Niño-Southern Oscillation (ENSO) and other natural forcing mechanisms could have been recorded in tree growth rings. Because ENSO is known to have a very strong influence on the climate of South America (Neelin and Latif, 1998).

In South America, research on tree ring chronologies have been mostly conducted for climate record studies based on sampling from Chile and Argentina (Hughes et al., 1982); however, there have been a few studies in Brazil. The Schwabe 11-yr solar cycle has been found in tree rings from Southern Brazil (Rigozo et al., 2002, Rigozo et al., 2004, Nordemann et al., 2005) and Chile (Nordemann et al., 2005, Rigozo et al., 2006), and the fourth harmonic of Suess cycle (52 yr) has been found in tree ring data from Concórdia, Brazil (Rigozo et al., 2004) and Osorno, Chile (Nordemann et al., 2005). The 80–100 yr Gleissberg solar activity cycles have been found in samples from Southern Brazil (Rigozo et al., 2004) and Chile (Rigozo et al., 2006). Nordemann et al. (2005) observed that there was an increase of Osorno tree ring thickness in Chile during the intervals with low sunspot numbers (1800–1835 and 1875–1935) and the contrary during the intervals with high sunspot numbers (1725–1800, 1835–1850, and 1950–1991). This shows the susceptibility of the tree growth rings to long periods of variations in solar activity.

The mathematical analysis of ring thickness time series aims to identify the spatial and geophysical phenomena that caused the variations recorded each year during the tree's life. The method used includes spectral analysis by iterative regression and wavelet analysis. The study described in this work is based on a mathematical analysis of the time series of growth rings in trees sampled in Southern Brazil. Characteristic features in the variations of their thickness, such as periodicities, trends, and events, are examined in order to obtain a greater understanding of effects of solar activity, climatic, and geophysical phenomena on the South America continent.

Section snippets

Time series and analysis methods

For the time series used in this study: (1) The tree ring samples of *Araucaria angustifolia* species were collected in Severiano de Almeida (RS) from Brazil, lat.: 27° 25′S–long.: 52° 06′W—Altitude: 476 m. (Fig. 1A). (2)- The sunspot time series (Fig. 1B) were obtained from National Geophysical Data Center, Boulder, Colorado, http://www.ngdc.noaa.gov/. (3) The Southern Oscillation Index (SOI) (Fig. 1C) was obtained from the website http://www.cru.uea.ac.uk/cru/data/soi.htm. A spectral analysis by …

Results and discussion

These time series were studied by harmonic spectral (iterative regression) and by wavelet analysis. The tree ring thickness chronology was obtained averaging 12 different tree ring samples, in order to eliminate the noise caused by each tree's individual variations. Before determining the mean chronology of the location, a mathematical function that represents its individual growth trend was subtracted from every sample tree series. Then a mean time series was calculated for each sampled…

Conclusion

Sun–Earth relationship studies based on tree growth rings from Brazil showed interesting results. The main result is the observation in tree samples of periodicities associated to solar activity: Gleissberg cycle, fourth harmonic of the Suess cycle, Hale cycle, and Schwabe cycle. The 11 yr cycle showed that Severiano de Almeida tree ring growth was facilitated by an increase of solar activity. These results are consistent with Rigozo et al. (2004); however, in this work two new periodicities…

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Solar activity imprints in tree ring-data from northwestern Russia

2019, Journal of Atmospheric and Solar-Terrestrial Physics

Citation Excerpt :

…Thus, further research of solar contribution to global climate change and its evolution in different periods of time is necessary. The main solar cycles, such as the second harmonic Schwabe cycle (~5–5.8 years), Schwabe (~11 years), Hale (~22 years) and Gleissberg (~80–100 years) are discovered in the numerous temperature, precipitation and tree-ring records (Baliunas et al., 1997; Neff et al., 2001; Rigozo et al., 2002, 2004; 2007, 2008; Kasatkina et al., 2007a,b; 2018; Shumilov et al., 2007; Miyahara et al., 2008; Velasco and Mendoza, 2008; Yamaguchi et al., 2010; Mufti and Shah, 2011; Prestes et al., 2011; Echer et al., 2012; Wang and Zhang, 2011; Frigo et al., 2013; Wiles et al., 2014; Muraki et al., 2015; Edvardsson et al., 2016; Perone et al., 2016; Sunkara and Tiwari, 2016; Zhao et al., 2017). Nowadays, the following solar factors acting on atmosphere and climate are considered: total solar irradiance (TSI) (Lean et al., 2005); UV radiation and its effect on stratospheric chemistry, ozone abundance and thermal structure (Haigh, 1996); galactic cosmic rays (GCR) affecting the cloud cover in the low atmosphere (Svensmark and Friis-Christensen, 1997; Marsh and Svensmark, 2000; Palle and Butler, 2001; Svensmark, 2007) through the ion-induced nucleation (Arnold, 1982, 2006; Yu and Turco, 2001; Carslaw et al., 2002; Harrison and Carslaw, 2003; Kirkby, 2007) and/or aerosol charging mechanism (Tinsley and Deen, 1991; Tinsley et al., 2000; Carslaw et al., 2002; Tripathi and Harrison, 2002; Harrison and Carslaw, 2003), and, as a consequence, changing the radiation balance.…

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The Medieval Climate Anomaly in South America

2019, Quaternary International

Citation Excerpt :

…Prominent solar minima have resulted in major hydroclimatic disruptions on the continent and are interpreted to have shifted the ITCZ southwards, possibly affecting the Atlantic Meridian Overturning Circulation (Chambers et al., 2014; Moreira-Turcq et al., 2014). The 11 and 22 years Schwabe and Hale solar cycles have been found in South American palaeohydroclimatic archives (Black et al., 2004; Gusev and Martin, 2012; Heredia and Elias, 2013; Hernández et al., 2010; Mauas et al., 2011), as well as in tree rings (Nordemann et al., 2005; Perone et al., 2016; Prestes et al., 2011; Rigozo et al., 2007, 2008a, 2008b). Variability in the Peru-Chile upwelling appears also to be influenced by solar activity changes, especially by the solar Gleissberg cycles with a periodicity of 80–100 years (Agnihotri et al., 2008; Guiñez et al., 2014).…

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Evidence of solar activity and El Niño signals in tree rings of Araucaria araucana and A. angustifolia in South America

2016, Global and Planetary Change

Citation Excerpt :

…The relationships between solar variability and the SSN, however, warrant further studies to discriminate their long-term effects. It is also necessary to indirectly monitor solar variation and geophysical phenomena that can have direct effects on climate (e.g., solar flares and volcanic eruptions) (Prestes et al., 2011). For example, during the Maunder minimum (1645–1715), solar and SSN minima occurred (Eddy, 1976), coinciding with a cold period referred to the “Little Ice Age”.…

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2013, Dendrochronologia

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2012, Journal of Atmospheric and Solar-Terrestrial Physics

> *Citation Excerpt :*
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> …It is worth to note that during 1955–1965 a weak solar cycle was observed and may explain the intermitted period observed in the cross-analyses with the meteorological parameters. These results are supported by recent evidences which demonstrate a strong relationship between solar activity and tree ring growth (Rigozo et al., 2008; Prestes et al., 2011; Wang and Zhang, 2011). The results from Figs. 6 and 7 indicate that temperature and rainfall may respond similarly to solar forcing, although in a different time lag.…

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