ScienceDirect

Journal of Atmospheric and Solar-Terrestrial Physics
Volume 71, Issue 1, January 2009, Pages 41-44

Multi-resolution analysis of global surface air temperature and solar activity relationship

M.P. Souza Echer [a b], E. Echer [b], D.J.R. Nordemann [b], N.R. Rigozo [a b c]

Show more

https://doi.org/10.1016/j.jastp.2008.09.032
Get rights and content

Abstract

In this work the surface temperature anomaly (dTG) and sunspot number (R_z) time series in the period 1880–2000 are studied with wavelet multi-resolution analysis. We found a very low correlation of 0.11 between dTG and R_z in the 11-yr-solar cycle band. A higher correlation of 0.66 is found in the ~22-yr-band with zero lag correlation coefficient between dTG and R_z. Furthermore, the long-term trend is markedly different between dTG and R_z. This might occurs because of the long-term warming on the last century, which is attributed mainly to anthropogenic effects.

Introduction

A clear warming trend in the global climate, of about 0.6°C, is observed in the last ~150yr in the global surface air temperature data. A large part of this warming is attributed to the anthropogenic effects due to the enhanced greenhouse gases concentrations (Parker et al., 1994; Jones et al., 1999; Intergovernmental Panel on Climate Change, 2001). Nevertheless, there seems to be some evidence that solar variability can contribute at least to part of this global warming (Reid, 1987; Hoyt and Schatten, 1997; Haigh, 1999; Lean and Rind, 1999; Pulkkinen et al., 2001; Oh et al., 2003; Raspopov et al., 2004).

The 11-yr-solar cycle and the associated variability that it has on the electromagnetic environment of Earth—the geospace—have been largely studied in the last decades (Eddy, 1976; Rigozo et al., 2001). Evidences for solar influences on weather and climate have been found in the last ~150yr, but without a conclusive physical mechanism to explain them and with many correlation breakdowns and/or reversals (Pittock, 1978; Herman and Goldberg, 1978; Hoyt and Schatten, 1997 and references therein). Despite this, empirical evidences seem to support the hypothesis of a long-term (decadal–multidecadal–centennial) solar forcing on climate. Among these evidences there is the near coincidence between the climatic extreme Medieval Optimum and the Little Ice Age with solar activity Grand Maxima and Minima —Medieval Maximum (centuries XII–XIII) and Maunder Minimum (~1645–1715). Furthermore, the present global warming is coincident with a Modern Maximum in solar activity. It seems plausible to state that the Sun was the main factor in the long-term climatic variation before industrial age, after which the enhanced greenhouse gases concentration played the main role. However, the Sun still may have an important role in climate variability today (Hoyt and Schatten, 1997; North and Stevens, 1998; Pulkkinen et al., 2001; Souza Echer et al., 2007, Souza Echer et al., 2008). The exact mechanism by which the solar activity can control the climate is being widely investigated. The discovery of solar irradiance variation with solar cycle, although with a very small amplitude (~0.1%), led to several works hypothesizing on a larger variation in solar irradiance over longer timescales (Solanki and Fligge, 1999; Frohlich and Lean, 2004). Other mechanisms, such as cloud cover/atmospheric electric field variation by galactic cosmic rays, which are modulated by the interplanetary magnetic field (IMF), have been proposed (Svensmark and Friis-Christensen, 1997; Tinsley, 2000; Pulkkinen et al., 2001). Spectral irradiance variations and their effects on the stratosphere (Haigh, 2007) and Sun–QBO coupling (Labitzke and van Loon, 1988) could be other mechanisms through which the solar activity may influence the climate.

In the present work, a multi-scale analysis of the relationships between solar-climate variations is performed. The time series used are the global temperature anomaly series (dTG) from Goddard Institute for Space Studies (GISS), available since 1880, and the sunspot number (R_z) as an index of global solar activity. The analysis is conducted using the multi-resolution wavelet analysis that enables us to decompose a signal in different timescales. Correlation and spectral analysis are then performed in each level.

Section snippets

Data and methods

The time interval used in this study is 1880–2000. The longest solar activity index is the sunspot number, which was first compiled by R. Wolf in the XIX century and is available as annual averages since 1700 (Eddy, 1976; Hoyt and Schatten, 1997). R_z is defined as $k(10g+f)$, taking into account the number of individual spots (f) and groups of spots (g) visible on solar disc and a factor (k) to correct observation differences. The annual averages of R_z were obtained from the Sunspot Index Data…

Results and discussion

Fig. 1 shows the annual averages of sunspot number (red) and temperature anomalies (blue) in the first panel. The following panels show the decomposition levels, from D_1 to the scaling level A_5, with the same color code as for the original data. Sunspot number shows a cyclical variation with a cycle minimum reaching the same level than the minimum of the preceding cycle. The solar activity is low at the end of XIX century and at the beginning of the XX century, increasing after ~1935. This…

Conclusions

We have studied in this work the global surface temperature dependence on solar activity over different timescales. We have observed that the higher correlation of dTG with R_z occurs around the 22 yr solar cycle band. The 11 yr signal in dTG is highly non-steady, being weaker around 1920–1960. This non-steady behavior can be the cause of very low correlation found with R_z in the entire period and also of the change of correlation with time reported in several studies. Finally, the long-term trend …

Acknowledgments

The authors thank the GISS/NASA, SIDC and NGDC/NOAA for global surface temperature, sunspot number and the geomagnetic index data. Authors also thank the support granted by M.P Souza Echer FAPESP post-doctoral fellowship (2006/467-2) and to T.P Souza Echer. E. Echer-FAPESP (2007-52533-1) and to CNPq (PQ 300104/2005-7).…

Recommended articles

References (38)

J.D. Haigh

Modeling the impact of solar variability on climate
Journal Atmospheric and Solar-Terrestrial Physics (1999)

J. Lean *et al.*
Evaluating sun-climate relationships since the Little Ice Age
Journal Atmospheric and Solar-Terrestrial Physics (1999)

H.S. Oh *et al.*
Multi-resolution time series analysis applied to solar irradiance and climate reconstructions
Journal Atmospheric and Solar-Terrestrial Physics (2003)

H. Svensmark *et al.*
Variation of cosmic ray flux and global cloud coverage- a missing link in solar-climate relationships
Journal of Atmospheric and Solar-Terrestrial Physics (1997)

E. Echer
Multi-resolution analysis of global total ozone column during 1979–1992 Nimbus-7 TOMS period
Annales Geophysicae (2004)

E. Echer *et al.*
Prediction of solar activity on the basis of spectral characteristics of sunspot number
Annales Geophysicae (2004)

J.A. Eddy
The Maunder minimum
Science (1976)

C. Frohlich *et al.*
Solar radiative output and its variability: evidence and mechanisms
Astronomy and Astrophysics Review (2004)

J.D. Haigh
The Sun and the Earth's climate
Living Reviews in Solar Physics (2007)

J. Hansen *et al.*
Global surface air temperature in 1995: return to pre-pinatubo level
Geophysical Research Letter (1996)

View more references

Cited by (25)

Inferring geoeffective solar variability signature in stratospheric and tropospheric Northern Hemisphere temperatures
2018, Journal of Atmospheric and Solar-Terrestrial Physics

Show abstract

Spatiotemporal investigation of long-term seasonal temperature variability in Libya
2016, Atmospheric Research

Show abstract

Solar activity cloudiness effect on NH warming for 1980-2095

2016, Advances in Space Research

Citation Excerpt :

…Many works have attempted to estimate the impact of solar variability on climate through solar or solar-associated phenomena such as the sunspots or geomagnetic activity (e.g. Dobrica et al., 2009; Paluš and Novotná, 2009; Souza-Echer et al., 2009; Kossobokov et al., 2010), the total solar irradiance (TSI) (e.g. Lean et al.,1995; Cubasch and Voss, 2000; Kristjánsson et al., 2002; Shindell et al., 2006; Mendoza and Velasco, 2009), the ultraviolet radiation (e.g. Haigh, 1996; Shindell et al.,1999), the solar wind modulation of the global-electric circuit (Tinsley, 2000), and the galactic cosmic rays (GCR) flux (e.g. Tinsley and Dean, 1991; Pudovkin and Veretenenko, 1995; Marsh and Svensmark, 2000; Pallé-Bagó and Butler, 2000; Svensmark, 2007)....

Show abstract

Possible effects of atmospheric teleconnections and solar variability on tropospheric and stratospheric temperatures in the Northern Hemisphere

2014, Journal of Atmospheric and Solar-Terrestrial Physics

Citation Excerpt :

…A quantitative examination of the association between solar activity, described by the sunspot number, and terrestrial climate indicated by global temperatures revealed that a linear relation exists between the two parameters through the recent 135 years (Stauning, 2011). Some studies claim that the correlation of temperature anomaly with sunspot numbers is higher around the 22 year solar cycle band, which apparently has a higher impact over temperature than the 11 year cycle for both hemispheres (Souza Echer et al., 2009, 2011). Gray et al. (2010) show that proofs for solar impact on climate do exist but their quantification is still under debate....

Show abstract

Variability of rainfall and temperature (1912-2008) parameters measured from Santa Maria (29°41'S, 53°48'W) and their connections with ENSO and solar activity

2012, Journal of Atmospheric and Solar-Terrestrial Physics

Show abstract

On the relationship between global, hemispheric and latitudinal averaged air surface temperature (GISS time series) and solar activity

2012, Journal of Atmospheric and Solar-Terrestrial Physics

Citation Excerpt :

…Kane and Teixeira (1990) found a 69 years period in their analysis of global temperature during 1851–1984 and Schlesinger and Ramankutty (1994) have also reported an oscillation of 65–70 years. This oscillation could be related to the Gleissberg solar cycle (80 years) (Hoyt and Schatten, 1997) or it could be an internal climate oscillation (Souza Echer et al., 2009). For the Southern Hemisphere and for the region 24° South to 44° South, it seems that there is a relevant periodicity longer than 126 years....

Show abstract

View all citing articles on Scopus

View full text