Geofísica Internacional (2004), Vol. 43, Num. 2, pp. 287-294

ENSO influence on tree ring data from Chile and Brazil

Nivaor Rodolfo Rigozo[1,2], Daniel J. R. Nordemann[2], Ezequiel Echer[2] and Luis Eduardo Antunes Vieira[2]

[1] *Faculdade de Tecnologia Thereza Porto Marques – FAETEC, Jacareí, Brazil*

[2] *Instituto Nacional de Pesquisas Espaciais – INPE, São José dos Campos, Brazil*

Received: March 31, 2002; accepted: August 27, 2002

RESUMEN

Se llevó a cabo un análisis espectral mediante el método de Ondículas en anillos de árboles de Brazil (27°11'S, 51°59'W) y Chile (49°12'S, 73°50'W) durante 1876-1994. También se aplicó este método a la Oscillación del Sur, SOI, representativa del ENSO, y a la Temperatura Media Superficial del Aire (GAST). Se seleccionó el rango de 2 a 8 años para su estudio. Como era de esperarse, se observan fluctuaciones en todos los datos, las cuales indican la existencia del ENSO. Se alternan amplitudes fuertes y débiles y corrimiento de frecuencias en las señales. Las señales más fuertes se observaron en la banda de 4-8 años en los árboles chilenos entre 1906-1920 y 1930-1950, y en los árboles brasileños en las bandas de 6-8 años alrededor de 1906 y 1950. El espectro de SOI presentó un mayor número de amplitudes intensas y el espectro de GAST mostró un alta intensidad solamente entre 1906 y 1928, en la banda de 5 a 8 años. Estos resultados muestran una clara evidencia de la influencia del ENSO en el crecimiento de los árboles.

PALABRAS CLAVE: Datos de los anillos de árboles, análisis espectral con Ondículas, fenómeno ENSO.

ABSTRACT

Wavelet spectral analysis was made in tree ring width data from Brazil (27°11'S, 51°59'W) and Chile (49°12'S, 73°50'W) over the period 1876-1994. Southern Oscillation Index–SOI, representative of ENSO phenomena, and Global mean Surface Air Temperature (GAST) data have been analyzed by wavelet transform. A 2-8 year range was selected. Fluctuations were observed in all data, as expected; these indicate the ENSO imprint on tree-ring data. Strong and weak amplitudes alternate, and frequency shifts in the signal were observed. The strongest signals were observed in the 4-8 year band in Chilean tree ring data, near 1906-1920 and 1930-1950, and in Brazilian tree ring data in the 6-8 year band near 1906 and 1950. SOI spectrum presented a larger number of intense amplitudes as expected, and GAST spectra showed high intensity only in 1906-1928, in the 5-8 year band. The results show a clear ENSO influence on tree growth.

KEY WORDS: Tree ring data, time series, wavelet spectral analysis, ENSO phenomenon.

INTRODUCTION

The El Niño Southern Oscillation - ENSO is a recurrent activity of the ocean-atmosphere system, which causes large-scale heating of the Pacific ocean every 4 years approximately (Enfeld, 1989; Neelin and Latif, 1998). El Niño was first reported in 1525 (Enfeld, 1989). ENSO is one of the most important geophysical phenomenon resulting from ocean-atmosphere coupling. The oceanic component El Niño is the warm phase, when the Pacific ocean water is heated, and it alternates with a cold phase, La Niña. The atmospheric component is the Southern Oscillation, a surface pressure gradient oscillation between the East and Western Pacific. The Southern Oscillation Index SOI is used to represent the ENSO phenomena. It is calculated from the monthly or seasonal fluctuations in air pressure difference between Tahiti and Darwin, Australia (Ropelewski and Jones, 1987). Positive values of SOI indicate La Niña events and negative values of SOI indicate El Niño events (Enfeld, 1989; Neelin and Latif, 1998). ENSO has a very strong influence on climate in South America. Through teleconnections it may cause climate anomalies in remote locations of the world, including droughts in Africa and floods in North America (Neelin and Latif, 1998). Southern Brazil and Chile have high annual positive precipitation anomalies in periods of El Niño (Dai and Wigley, 2000).

Tree rings have been used to reconstruct past climate and solar variabilities (Dutilleul and Till, 1992; Hughes *et al.*, 1982; Kurts *et al.*, 1993). The growth of trees depends on the amount of water precipitation and on temperature. It is expected that precipitation and temperature fluctuations caused by ENSO, and others temperature forcing mechanisms, could influence tree growth. In South America, research with tree ring chronologies was made with climate records from Chile and Argentina (Hughes *et al.*, 1982). A new methodology was developed by Rigozo (1998) to study solar activity and others geophysical signals in tree-ring samples. Rigozo (1998), Rigozo and Nordemann (1999), Rigozo *et al.* (2002a, b, c) and Vieira *et al.* (2001) have identified the 11 year solar cycle in tree-ring samples from southern Brazil, using spectral analysis. Studies of last century solar-geomagnetic-ENSO signals in tree ring data over the southern Brazil and Chile were made by Vieira *et al*. (2001) and of solar-ENSO signals in tree ring data over southern Brazil by Rigozo *et al*. (2002b).

In this paper a wavelet spectral analysis of climatic parameters, Global mean Surface Air Temperature (GAST) (Hansen and Lebedeff, 1987) and ENSO, is used for SOI time series and tree ring width, between 1876-1994. Data are from Concordia, southern Brazil (27°11'S, 51°59'W; Alt: 640 m) and Pio XI Glacier, Chile (Rivera and Casassa, 1999; 49°12'S, 73°50'W, Alt. 25 m). In order to study the influence of ENSO and GAST signals on tree rings from Chile and Brazil, wavelet spectrum analysis and cross-wavelet spectrum analysis were applied to the annual data average.

METHODOLOGY

The southern Brazilian tree ring data is based on 13 chronologies compiled by Rigozo (1998) and obtained from a specimen of Brazilian *Araucaria angustifolia* native species. The Chilean tree ring data is based on 5 chronologies (Vieira *et al*., 2001) and obtained from specimen of *Pilgerodendron uviferum*. Annual averages of SOI and GAST were used in this analysis. For not having given climatic in the places of collection of the tree samples, our hypothesis about the climate response in the tree-ring data for this region is based on the global temperature anomalies. The annual global temperature anomalies come from about 4000 meteorological stations around the world. These data are an update of the analyses described by Hansen and Lebedeff (1987, 1988). These data are available in the Goddard Institute for Space Studies (GISS). SOI data were obtained from Bureau of Meteorology of Australia.

The wavelet transform is a very powerful tool to analyze non-stationary signals. It permits the identification of main periodicities in a time series and the evolution in time of each frequency (Kumar and Foufoula-Georgiou, 1997; Torrence and Compto, 1998; Percival and Walden, 2000). The wavelet transform of a discrete data series is defined as the convolution between the data series with a scaled and translated version of the wavelet function chosen. By varying the wavelet scale and translating in time, it is possible to construct a picture showing the amplitude of any characteristics versus scale and how this amplitude varies with time.

In this work, the complex Morlet wavelet analysis was used because it is the most adequate to detect variations in the periodicities of geophysical signals in a continuous way along time scales (Torrence and Compto, 1998; Percival and Walden, 2000). Also the cross-wavelet spectrum between each time series was calculated. The cross-wavelet power indicates the scales of higher covariance between two time series (Torrence and Compto, 1998).

RESULTS AND DISCUSSION

The Morlet wavelet transform was applied to all data. In this work only the 2-8 year range is studied, because the ENSO periodicities occur mainly in this interval. In Figures 1 to 4, the time series of data and its Morlet Wavelet Spectrum are presented; and in Figures 5 to 10 the cross-wavelet spectra are shown.

In Figure 1, in the upper panel (a) the tree ring width data from southern Brazil is shown, and in the lower panel, (b), the Morlet wavelet spectrum of Brazilian tree ring data is presented. In Figure 2, in the upper panel (a) the tree ring width data from Chile is shown, and in the lower panel, (b), the Morlet wavelet spectrum of Chilean tree ring data is presented. In Figure 3, in the upper panel (a) the SOI time series is shown and in the lower panel (b) the Morlet wavelet spectrum of SOI time series is presented. In Figure 4, in the upper panel (a) the Global mean Surface Air Temperature (GAST) time series is shown and in the lower panel (b), the Morlet wavelet spectrum of GAST is presented.

The wavelet spectral analysis shows the presence of short-term variations, between 2 and 8 years, in tree ring and global temperature data (Figures 1, 2 and 4). These variations represent the signature of ENSO events (Figure 3), and they were also observed in SOI, as expected.

The wavelet spectral analysis of tree ring data, from Brazil (Figure 1) and Chile (Figure 2), show signals between 2 and 8 years. Intense signals were observed in tree ring data from Chile at 1906 (2-3 year band) and between 1930-1950 (3-8 year band), as can be seen in Figure 2. An intense signal, within the 6-8 year band, was observed in tree ring data from Brazil around 1950 and a signal weaker close to 6 year, around 1906 (Figure 1).

The wavelet spectral analysis of GAST (Figure 4) data shows an intense signal, within the 4-8 year band, at the time interval between 1906-1928. This intense signal was also observed in SOI wavelet spectrum (Figure 3) for the same period and same band. The wavelet spectral analysis of SOI index also shows a signal at a period close to 1950 year, within the 5-6 year band.

In Figures 5, 6, 7, 8, 9 and 10, the cross-wavelet spectrum between: tree ring width from Brazil and SOI, tree ring width from Brazil and GAST, tree ring width from Chile

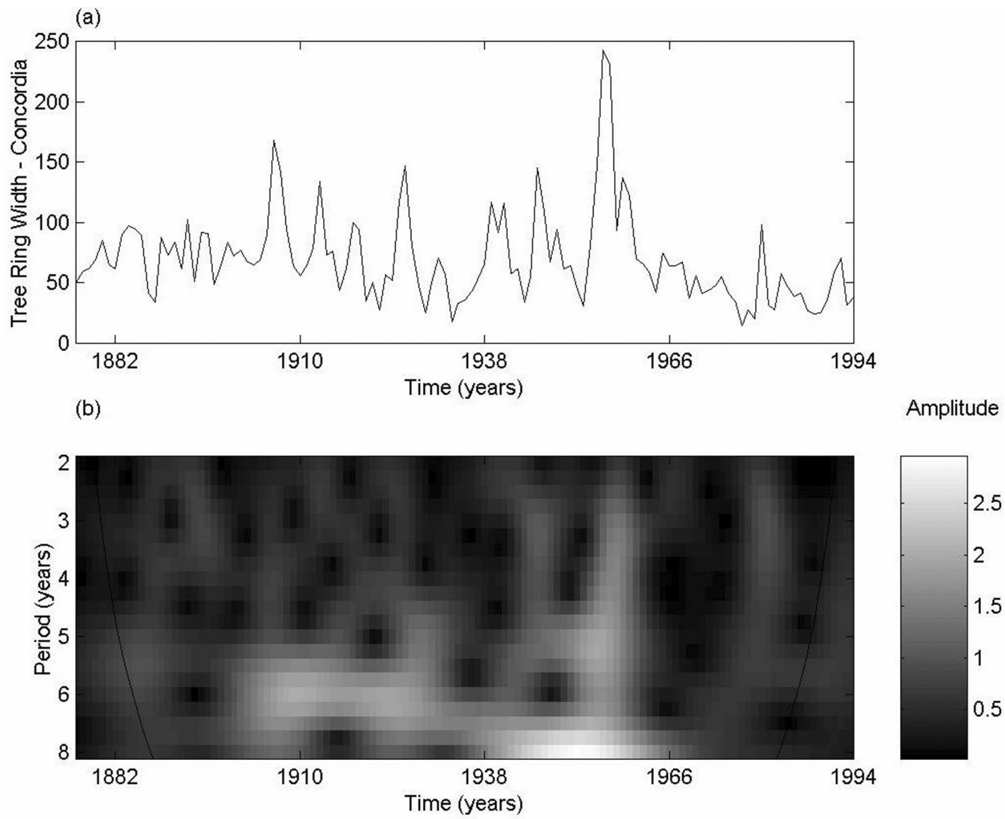

Fig. 1. a) Tree ring width data from Concordia, southern Brazil, 1876-1994. b) Morlet Wavelet Spectrum of tree ring data from Brazil.

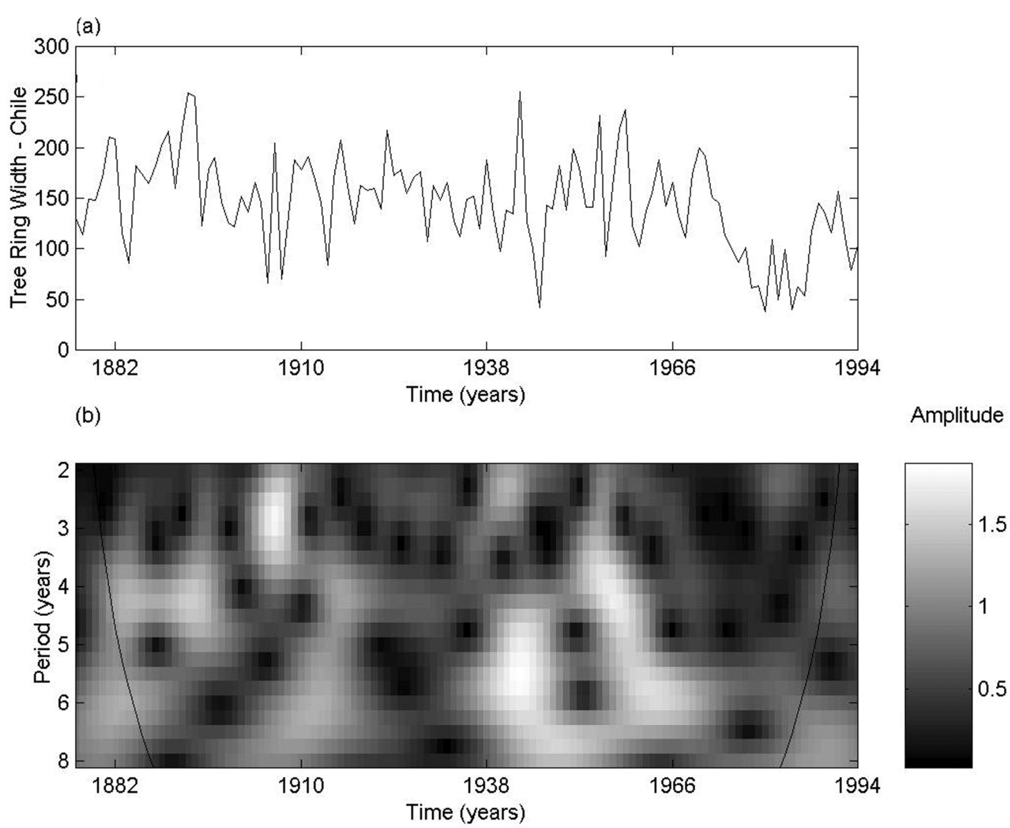

Fig. 2. a) Tree ring width data from Chile, 1876-1994 b) Morlet Wavelet Spectrum of tree ring data from Chile.

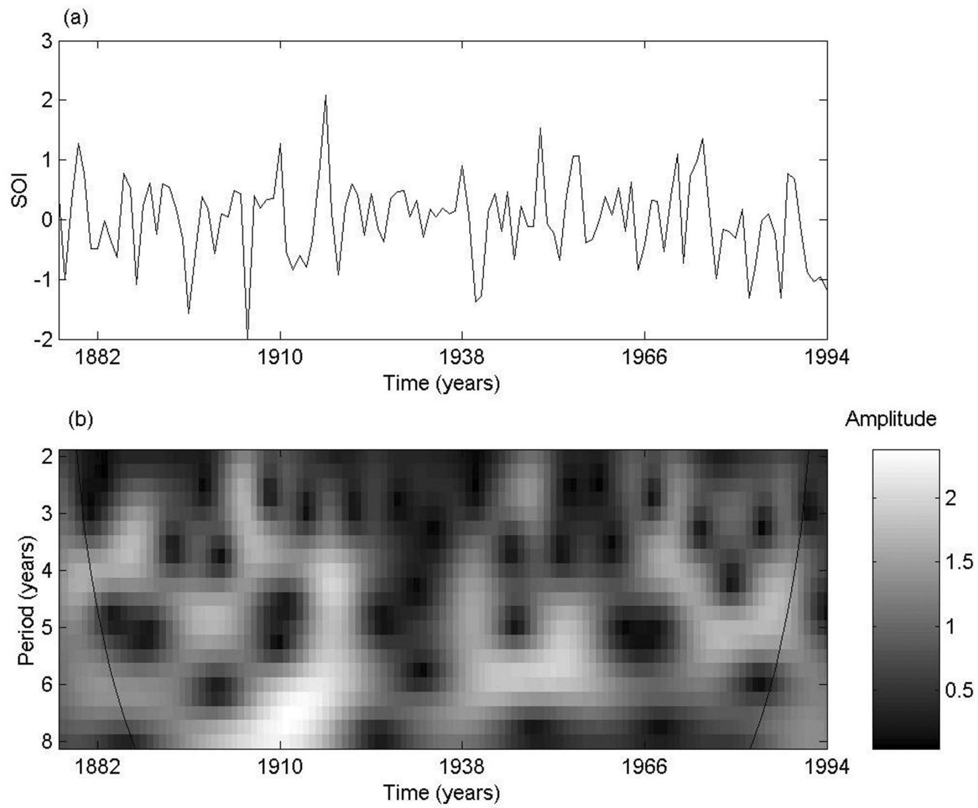

Fig. 3. a) Southern Oscilation Index – SOI time series, 1876-1994. b) Morlet Wavelet Spectrum of SOI time series.

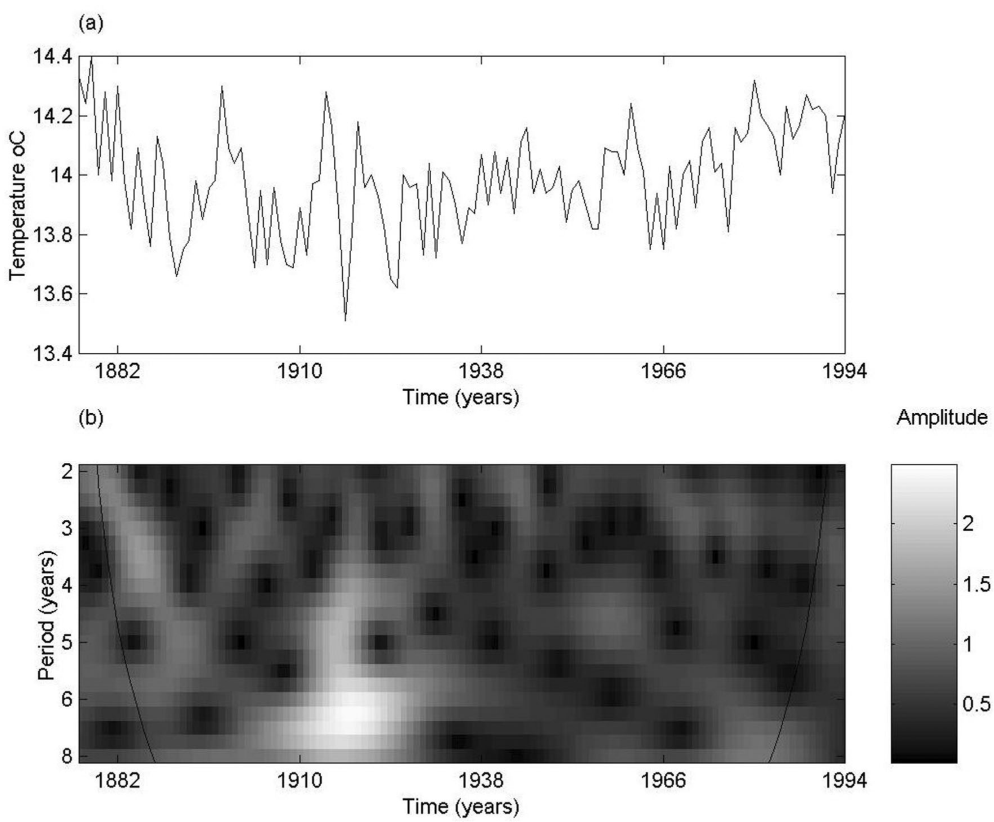

Fig. 4. a) Global mean Surface Air Temperature (GAST) time series, 1876-1994. b) Morlet Wavelet Spectrum of GAST.

and SOI, tree ring width data from Chile and GAST, SOI and GAST and tree ring width from Brazil and Chile, respectively, are presented.

The cross-wavelet spectrum between tree ring data from Brazil and SOI (Figure 5) shows two intense signals between 1906 and 1928, within the 5-8 year band, and between 1950 and 1960, within the 4-6 year band. Also it was observed between 1906 and 1928 a signal at 6 years for the cross-wavelet spectrum between tree ring data from Brazil and GAST data (Figure 6).

The wavelet spectral analysis of tree ring data from Chile and SOI (Figure 7) shows intense signals within the 2-4 year band in 1906, and within the 4-5 and 5-8 year bands between 1906 and 1928. Another intense signal, within the 4-7 year band, was observed between 1940 and 1950. The cross-wavelet spectrum between tree ring data from Chile and GAST data (Figure 8) shows an intense signal, within the 4-8 year band, between 1906 and 1928. Other weaker signals were also observed within 2-3 and 4-5 year bands.

The cross-wavelet spectral analysis of SOI and GAST (Figure 9) shows a clear signal between 1906 and 1928 within the 5-8 year band. These results show a clear evidence of the climatic influence over growth tree ring. The cross-wavelet spectral analysis of tree ring data from Brazil and Chile (Figure 10) shows an intense signal, at 8 year, close to 1950, and a signal at 3-5 year band around 1960. It was also observed between 1906 and 1928 a weaker signal within the 5-7 year band.

The more intense amplitudes for SOI (Figure 3) were observed: i) in the 2-4 year band: 1880 1890; 1900-1920; 1965-1990; ii) in the 4-8 year band: 1900-1920; 1930-1960; 1970-1990. Torrence and Compto (1998) have analyzed SST (Sea

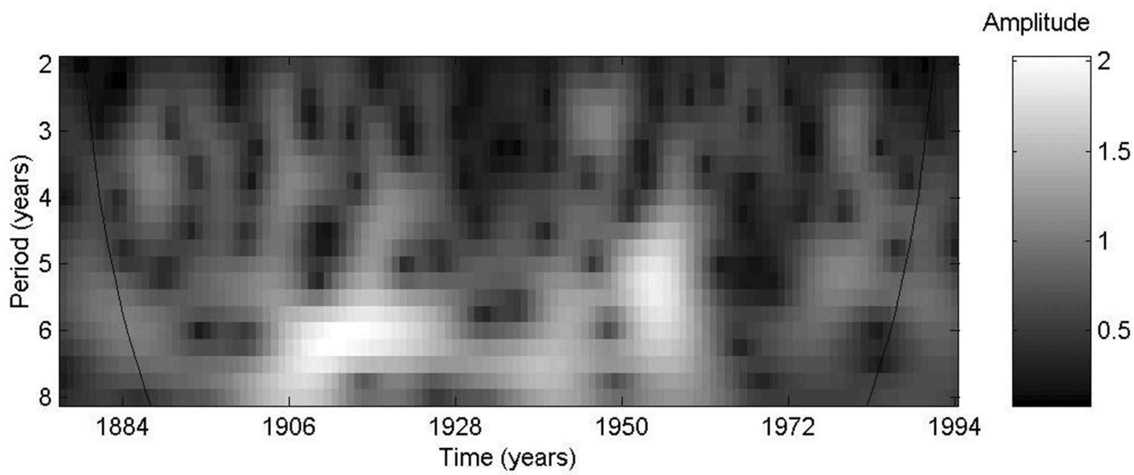

Fig. 5. Cross-wavelet spectrum between tree ring width data from Brazil and SOI.

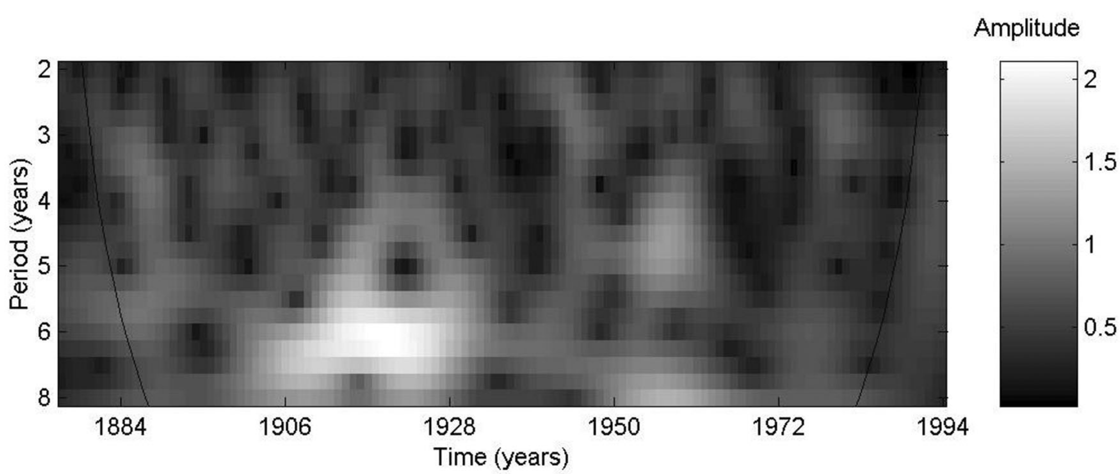

Fig. 6. Cross-wavelet spectrum between tree ring width data from Brazil and GAST.

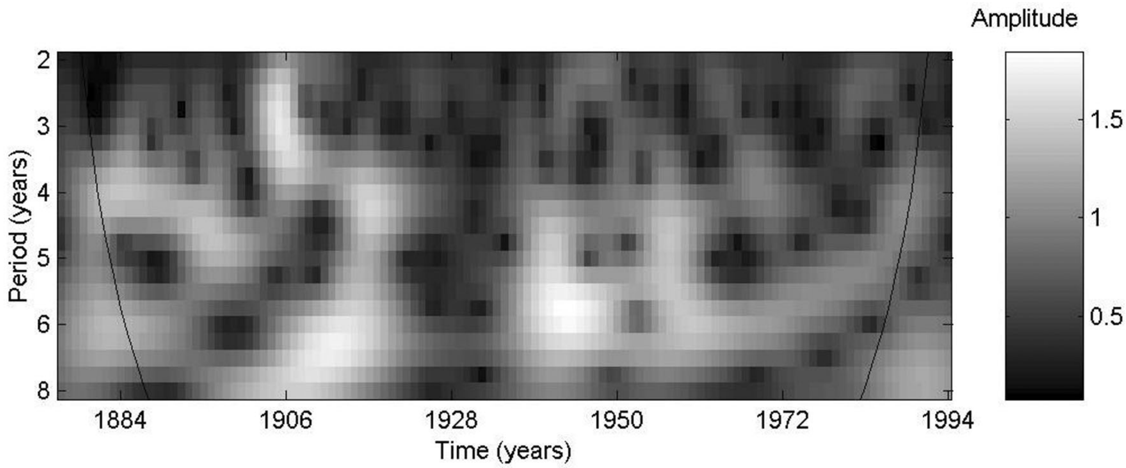

Fig. 7. Cross-wavelet spectrum between tree ring width data from Chile and SOI.

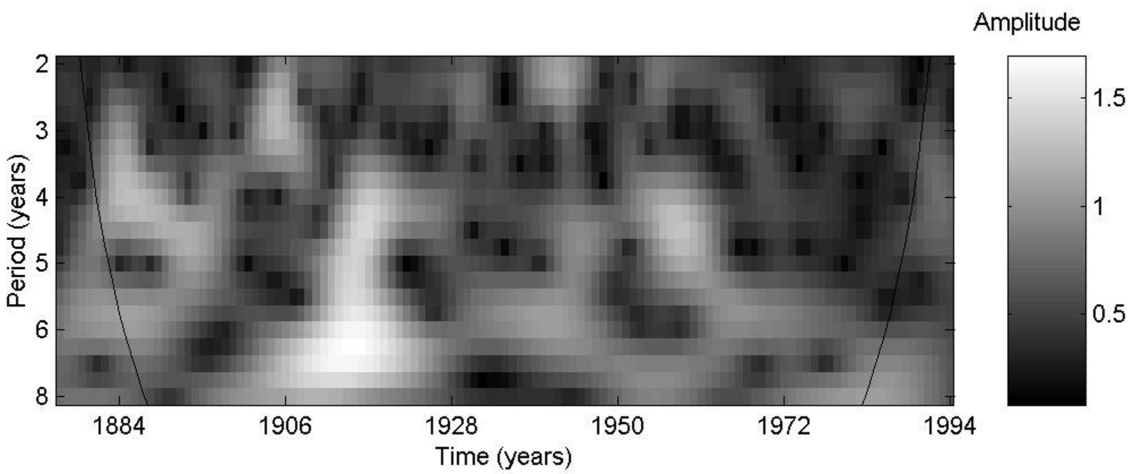

Fig. 8. Cross-wavelet spectrum between tree ring width data from Chile and GAST.

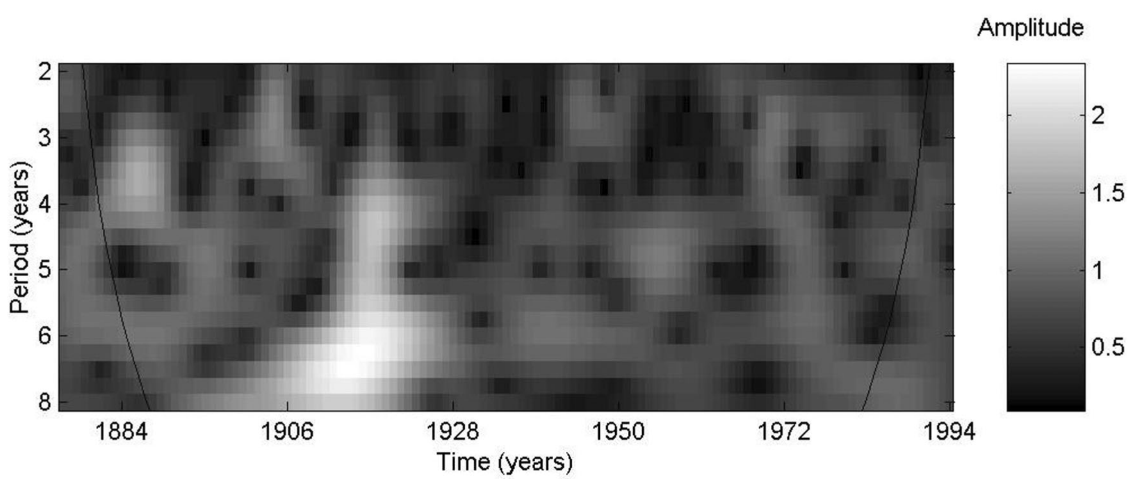

Fig. 9. Cross-wavelet spectrum between SOI and GAST.

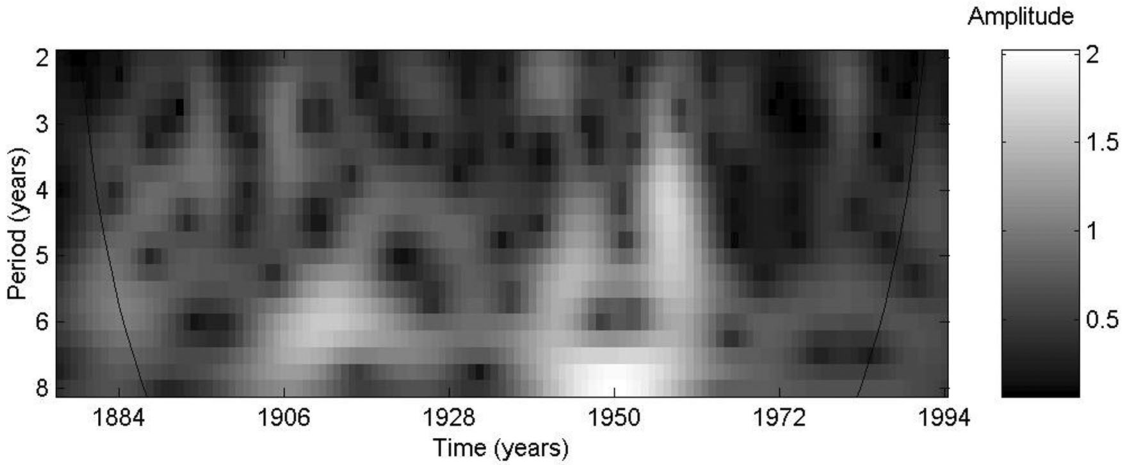

Fig. 10. Cross-wavelet spectrum between tree ring width data from Brazil and Chile.

Surface Temperature) data in the period 1871-1997. They have observed that the amplitude of the signal was more intense in the 2-8 year band, with however significant power on higher periods. The more intense signal was observed in the period 1880-1890 (4 years), 1900-1920 (4-8 years), 1920-1930 (2 years), 1965-1985 (2-4 years) and 1935-1960 (4-8 years). These results are in good agreement with the ones obtained in this work for the SOI data.

CONCLUSIONS

Wavelet spectral analysis applied to tree ring width data from Brazil and Chile, and SOI and GAST, showed that in the 2-8 year range there are many fluctuations and a signal alternating between strong and weak amplitudes. Both Brazil and Chile tree ring data show high correlation with SOI during some periods, and the presence of the ENSO signal recorded by tree ring data is visible. The GAST spectrum showed high intensity in the range studied only between 1906-1928, in the 5-8 year. These results show a clear evidence of the ENSO influence over the growth of tree rings.

ACKNOWLEDGEMENT

Thanks to Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP 02/12723-2) for Post doctorate fellowship (project number 98/16094-2), Doctorate fellowship (project number 98/04732-4), Doctorate fellowship (project number 99/07221-3); Research support (project number 99/03625-2). Thanks to CNPq (projeto n: 474185/2003-6) for Productivity in Research fellowship (project 300031/94-7).

BIBLIOGRAPHY

DAI, A. and T. M. L. WIGLEY, 2000. Global Patterns of ENSO-induced Precipitation. *Geophys. Res. Lett., 27,* 1283-1286.

DUTILLEUL, P. and C. TILL, 1992. Evidence of periodicities related to climate and planetary behaviors in ring-width chronologies of Atlas Cedar (*Cedrus Atlantica*) in Marocco. *Can. J. Forest. Res., 22,* 1469.

ENFIELD, D. B., 1989. El Niño, Past and Present, *Rev. Geophys., 27,* 159-187.

HANSEN, J. and S. LEBEDEFF, 1988. Global surface air temperatures: Update through 1987. *J. Geophys. Res., 15,* 323-326.

HANSEN, J. and S. LEBEDEFF, 1987. Global trends of measured surface air temperature. *J. Geophys. Res., 92,* 345-13, 372.

HUGHES, M. K., P. M. KELLY, J. R. PILCHER and V. C. LAMARCHE, 1982. Climate from tree ring, Cambridge University Press.

KUMAR, P. and E. FOUFOULA-GEORGIOU, 1997. Wavelet analysis for geophysical applications. *Rev. Geophys., 35*, 385-412.

KURTHS, J., C. SPIERING, W. MÜLLER-STOLL and U. STRIEGLER, 1993. Search for solar periodicities in Miocene tree ring widths. *Terra Nova, 5,* 359.

NEELIN, J. D. and M. LATIF, 1998. El Niño Dynamics, Physics Today, 32-36.

PERCIVAL, D. B. and A. T. WALDEN, 2000. Wavelet Methods for Time Series Analysis, Cambridge University Press.

RIGOZO, N. R. and D. J. R. NORDEMANN, 1999. Solar Activity Records in Tree-Ring. *Rev. Geofisica, 50,* 163-170.

RIGOZO, N. R., L. E. A. VIEIRA, E. ECHER and D. J. R. NORDEMANN, 2002c. Search for Solar Periodicities in Tree-Ring Widths from Concórdia (S.C., Brazil), PAGEOPH, in press.

RIGOZO, N. R., A. ZANANDREA, L. E. A. VIEIRA, E. ECHER and D. J. R. NORDEMANN, 2002b. Wavelet analysis of Solar-ENSO imprints in tree ring data from Southern Brazil in the last century (1876-1991), Climatic Change, in press.

RIGOZO, N. R., D. J. R. NORDEMANN, E. ECHER, A. ZANANDREA and W. D. GONZALEZ, 2002a. Solar Variability Effects Studied by Tree-Ring Data Wavelet Analysis. *Adv. Spa. Res., 29,* 1985 1988.

RIGOZO, N. R., 1998. Registros da atividade solar e de outros fenômenos geofísicos em anéis de árvores, PhD Thesis (Doctorate in Space Geophysics) - National Institute for Space Research, Brazil, 132p.

RIVERA, A. and G. CASASSA, 1999. Volume changes on PIO XI Glacier, Patagonia: 1975-1995. *Global and Planetary Change, 22*, 233-244.

ROPELEWSKI, C. F. and P. D. JONES, 1987. An extension of the Tahiti-Darwin southern oscillation index. *Mounthly Weather Review, 115*, 2161-2165.

TORRENCE, C. and G. P. COMPTO, 1998. A Pratical Guide to Wavelet Analysis. *Bull. Amer. Meteor. Soc., 79,* 61-78.

VIEIRA, L. E. A., E. ECHER, N. R. RIGOZO, D. J. NORDEMANN and A. DAL LAGO, 2001. Solar Geomagnetic-ENSO records in tree ring data from Southern America in the last century (1876-1991), EGS XXVI General Assembly, Nice, França, 25-30 Mar, Geophysical Research Abstracts, GRA3, 6998.

Nivaor Rodolfo Rigozo[1,2], Daniel J. R. Nordemann[2], Ezequiel Echer[2] and Luis Eduardo Antunes Vieira[2]

[1] Faculdade de Tecnologia Thereza Porto Marques – FAETEC, CEP 12308-320, Jacareí, Brazil
Fone: 55 12 39524231
[2] Instituto Nacional de Pesquisas Espaciais – INPE, CP 515, 12201-970 São José dos Campos, Brazil.
Fone: +55 (012) 345 6840
Fax: +55 (012) 345 6810
Email: rodolfo@dge.inpe.br