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RESEARCH

Ocean–atmosphere interaction identified in tree-ring time series from southern Brazil using cross-wavelet analysis

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Abstract
Tropical dendrochronology has gained significant attention in recent years, particularly with the dendrochronological study of new species that produce annual growth rings and are responsive to environmental changes. Despite the progress, the extent to which ocean–atmosphere interactions influence regional climate and, consequently, tree growth, is not fully understood. Among the new species, *Ocotea porosa (Nees & Mart.) Barroso* (also known as *Imbuia*) has shown excellent potential for climate research. This study investigates the climatic and solar influences on a chronology of 41 *Imbuia* tree samples. Pearson's correlation was used alongside Wavelet transform to evaluate periodicities between the tree-ring chronology and climatic parameters such as the southern-oscillation index (SOI), annual precipitation, *El Niño* 3.4 (PACE), and the South Atlantic Index (ATLS). Our analysis revealed evidence of the influence of the *El Niño* Southern Oscillation (SOI) on rainfall variability in the region, the Hale and Gleissberg solar cycles causing precipitation variation, likely due to the influence of the Atlantic Ocean, and the Brückner-Egeson-Lockyer climatic cycle, which is correlated with sunspot activity. Furthermore, our wavelet analysis identified possible connections to the Eastern Pacific-type *El Niño* events during five specific periods: 1911–1912, 1918–1919, 1976–1977, 1982–1983, and 1986–1987. The results indicate that southern Brazil is affected by several climatic and geophysical parameters from both the Atlantic and Pacific oceans, which directly affect the growth of *Imbuia* trees as their tree-ring series display sensitivity to these parameters.

1 Introduction

The Brazilian territory is influenced by both the Atlantic and Pacific oceans, which interact with the lower atmosphere in different ways. These include 1) the winds above the sea surface, which are responsible for cooling the sea surface and balancing the heat flux, and are the main mechanisms that generate ocean circulation; 2) the evaporation from the ocean mixing across the marine atmospheric boundary layer, and subsequently transporting moisture to the troposphere; and 3) the atmospheric circulation driven by water vapor resulting from evaporation from the ocean, which releases latent heat associated with condensation of the vapor to form clouds and precipitation (Chelton and Xie 2010).

This interaction between the oceans and the lower atmosphere can result in climatic phenomena such as the *El Ninõ* Southern Oscillation (ENSO). The ENSO is associated with changes in the Sea Surface Temperature (SST) patterns and trade winds in the Equatorial Pacific region. It is defined as positive (*El Ninõ*) and negative (*La Ninã*) anomalies (Sampaio 2000), affecting South America (Garreaud et al 2009; Rigozo et al 2012), and specifically, Southern Brazil. In Southern Brazil, the *El Ninõ* events coincide with a higher frequency of heavy rains, and the *La Ninã* events correspond to severe droughts. Floods and severe droughts can cause problems with tree growth performance. Tree growth is highly dependent on the rainfall amounts in the most humid sector during the dry season, whereas in sites settled in areas of lower summer temperatures, the rainfall during the warm-rainy season is the main determining factor

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