Multilevel ^{13}C-late-wood signatures from seasonal-drought-induced stress on ***Pinus pinaster*** during last 35 years

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Abstract

Keywords:

1. Introduction

This study aims to study long-term effects of drought on tree growth and isotopic discrimination of *P. pinaster* in north and east-central Spain.

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This is the introduction

2. Materials and Methods

2.1. Study area

We developed our study in two areas in north and east-center of the Iberian Peninsula (Fig. 1). The areas belong to the most vast native provenance region of maritime pine (*Pinus pinaster* Ait.), growing on sandy soils and forming large continuous populations at moderate densities (average of 500 - 1000 trees per hectarea). Average altitude for this region ranges from 900 m to 1000 m above sea level. Mean annual temperature is about 11 °C and mean annual precipitation is aprox. 562 mm. Forest ecosystems of the area are associated with oaks (*Quercus ilex* L., *Q. faginea* Lam., and *Q. pyrenaica* Willd.), beeches (*Fagus silvatica* L.), and other pine species (*Pinus sylvestris* L., *P. nigra* Arn. and *P. halepensis* Mill)

2.2. Core sampling

Dominant trees in ten sites on the maritime pine forests where core sampled (5 mm diameter) at chest height (1.3 m). The sample trees were located in five sites on northern study-site edge and other five sites on the center-east edge. Two dominant trees were sampled by site, and two core samples were extracted by tree. The core samples were air dried, sanded, and scanned (1000:1600 ppi). The tree-ring widhts in the scanned images where measured with R-package: `measuRing` (Lara et al., 2015), and statistically controlled with `dplR` package (Bunn, 2010).

A master chronology of *P. pinaster* with strong common signal (EPS $>$ 0.95, SNR $>$ 22), developed with core samples of 150 trees on ten sites of study area (Bogino and Bravo, 2008), was used to develop statistical control of the measured rings. The cross-dating process was developed on four common regions, defined after clustering tree-dimensional coordinates of the sites, with each of the clusters having sites at most 80 km of closeness (Figure **??**).

2.3. climatic data

We processed a high-resolution gridded dataset (0.11° resol.) of monthly mean temperatures for peninsular Spain: Spain02, (Herrera et al., 2015) to compute Standardized Precipitation Indexes (SPI) across Ebro basin (1971 - 2010). Proyection of UTM coordinates of the sample plots to coordinate system in climate algorithm was developed with R-package `rgdal` (Bivand et al., 2015). The SPIs were modeled from the extracted spatial precipitations with R-packages: `raster`(Hijmans, 2015) and `spi` (Neves, 2012).

2.4. ^{13}C-late-wood signatures

One core per site was used for isotopic analysis on late wood of the dated rings. Each latewood portion of rings was carefully separated from earlywood with a microtome. Only rings formed after 1974 were analysed. Whole wood was milled, an aliquot of 100 mg was packed in porous bags and used for cellulose extraction. The samples were washed in 5 percent NaOH solution twice for 2 h at 60 °C in order to remove fats, oils, resins and hemicellulose. In a second step the lignin was removed with NaClO 2.7% After each treatment the samples were washed with distilled water and then finally dried overnight at 60 °C.

The δ^{13}C was determined using an elemental analyser linked to an isotopic ratio mass spectrometer via a variable open split interface (Max Plank Institute for Biogeochemistry, Germany). The results of laboratory were presented in the δ notation:

$$\delta = [(R_{sample}/R_{standard}) - 1] \times 10^3 \quad (1)$$

relative to the internationsl VPDB standard for cabon; where R_{sample} and $R_{standard}$ is the fractions of ^{13}C/^{12}C for the sample and the standard, respectively. The standard deviation for the repeated analysis (commercial cellulose) was better than 0.1. was better than 0.1 percent. The calibration versus VPDB was done by measuring IAEA USGS-24(graphite) and IAEA-CH7 (polyethylene).

3. Results

3.1. dendroclimatic seasonal responses

Significance of seasonal responses of tree-diameter growth (TDG) to climate depended on the compared climatic variable. The TDG signifficantly responded to winter precipitations while relationships with the seasonal temperatures were not conclusive. The signifficant coefficients between TDG and within-winter precipitation were positive and stronger in southern- than in northern-study site. and occurred within a month of each other: i.e. February in the south, and Jannuary in north.

Likewise, seasonal responses of ICW to climate on both site localization and the compared climatic variable.

Likewise, the site localization determined relationships between ICW and the studied climatic variables. In northern-study site, The ICW signifficantly responded to summer temperatures. Non signifficant responses were evidenced between ICW and the studied seasonal temperatures of the north.

4. References

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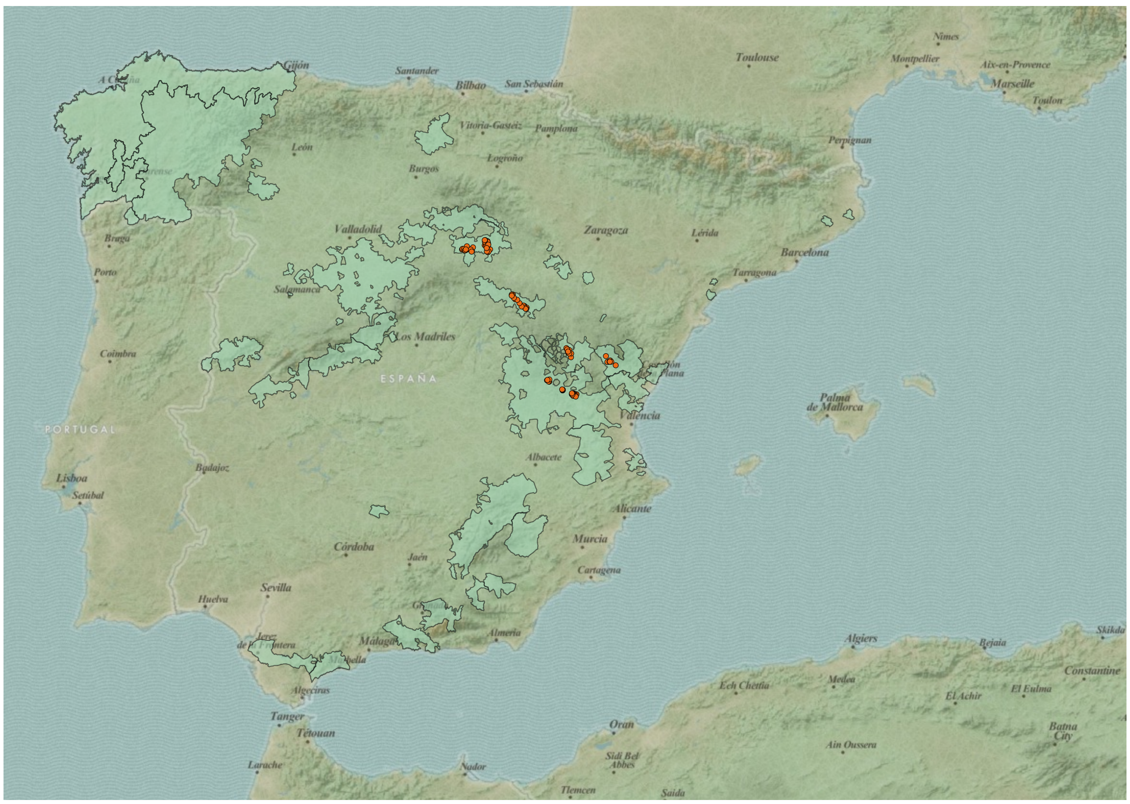

Figure 1: Study site. The green areas represent distribution of *P. pinaster* along Spain. The orange points represent locations of tree-ring chronologies only

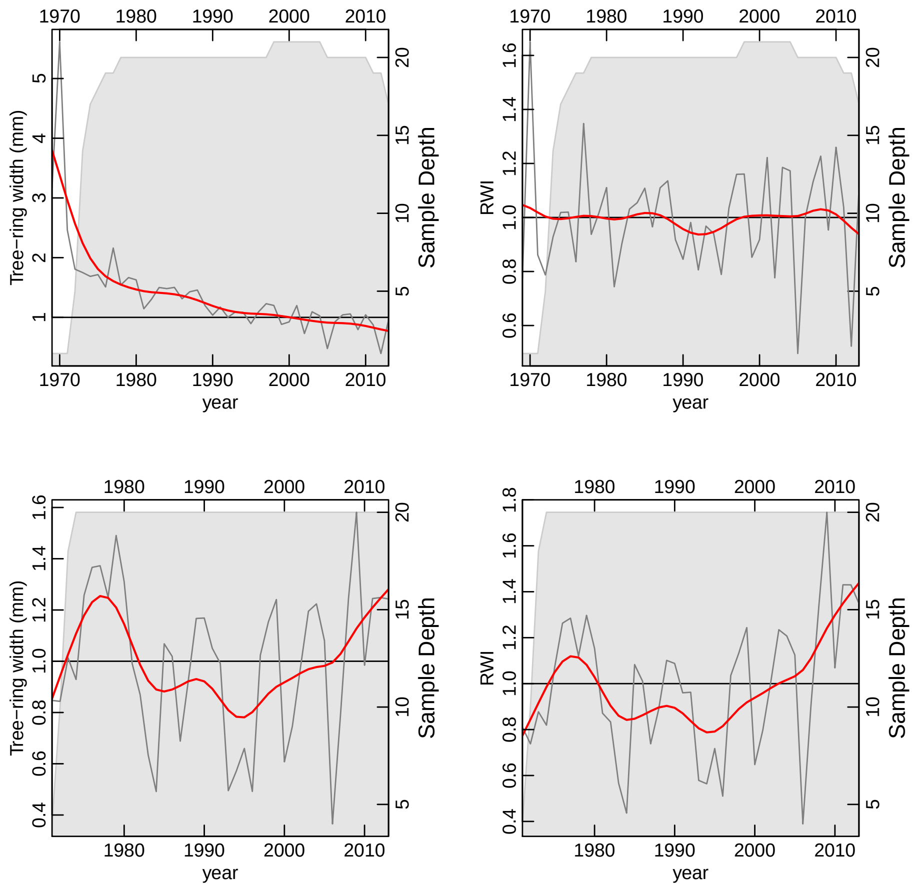

Figure 2: Tree-ring-width chronologies of *P. pinaster* trees growing on north (upper-panel plots) and east-central Spain (lower-panel plots). Trends in original chronologies (left-panel plots) are subtracted (right-panel plots). Gray lines indicate fluctuations, and red lines suggest average patterns. Sample depth is the number of series available in each year.

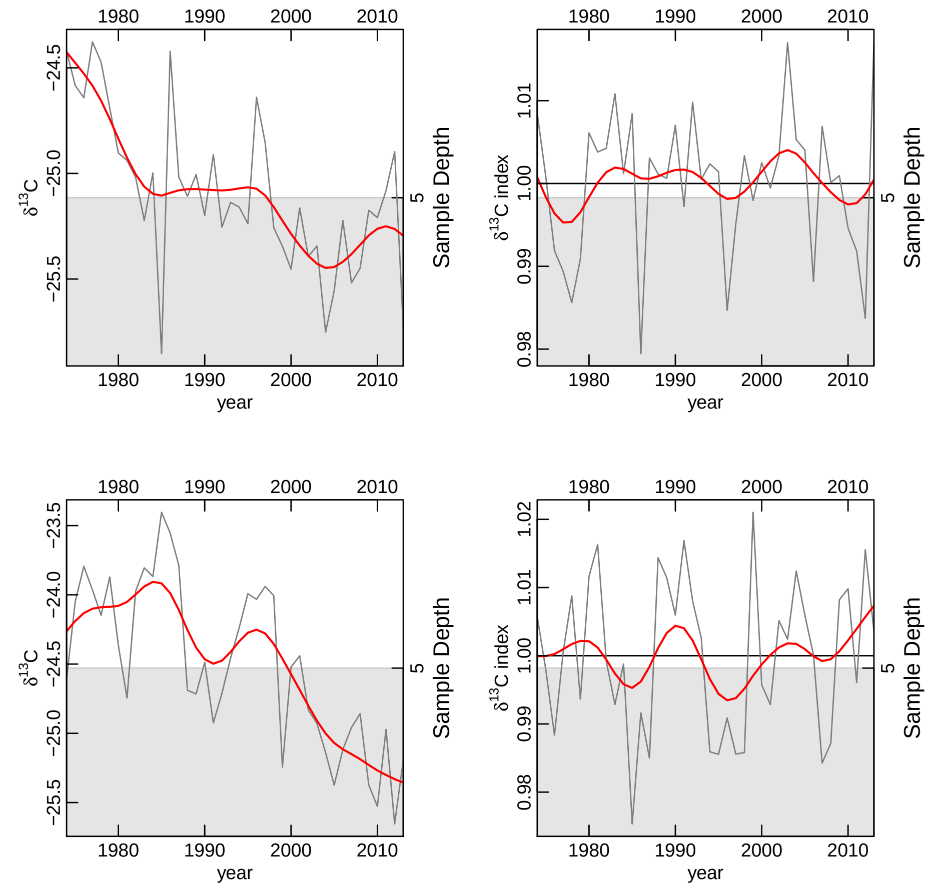

Figure 3: Isotopic chronologies of *P. pinaster* trees growing on north (upper-panel plots) and east-central Spain (lower-panel plots). Trends in original chronologies (left-panel plots) are subtracted (right-panel plots). Gray lines indicate fluctuations, and red lines suggest average patterns. Sample depth is the number of series available in each year.

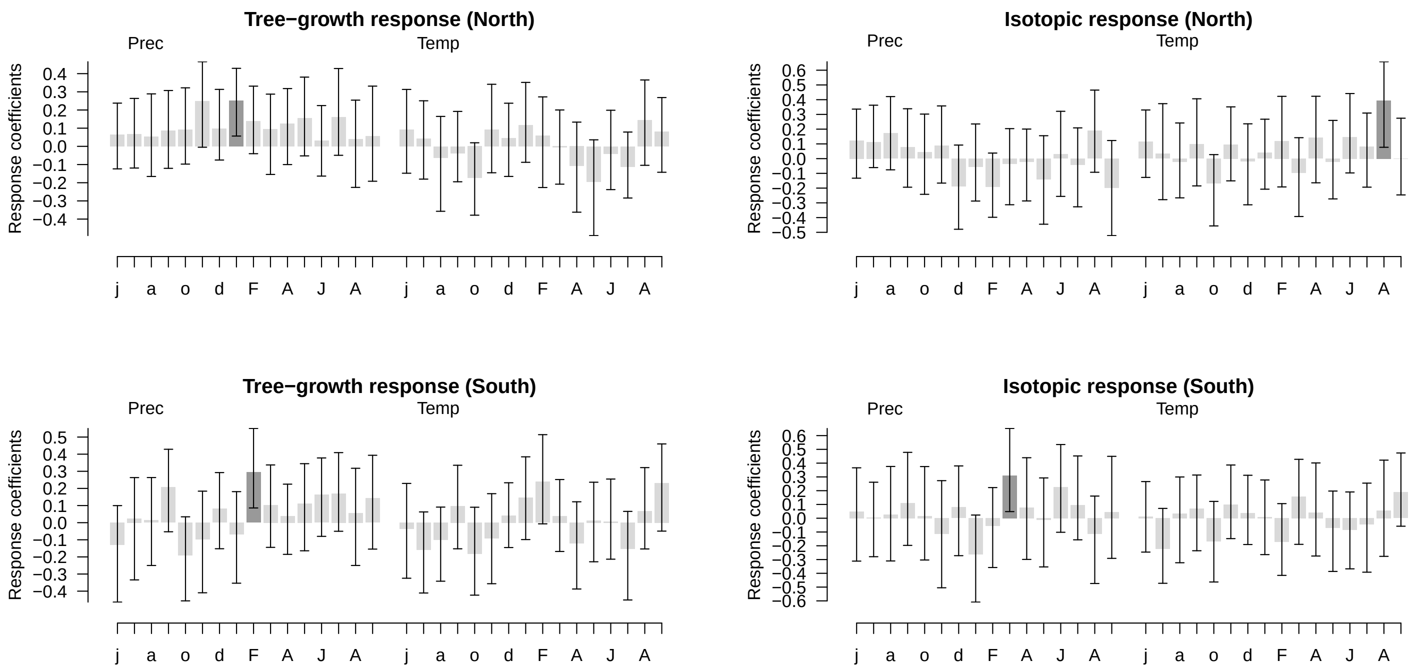

Figure 4: Intra-annual response coefficients for precipitation and temperature for tree-ring and isotopic chronologies of *P. pinaster*. The darker bars indicate signifficant coefficients ($P \leq 0.05$), and the lines represent 95%-confidence intervals.

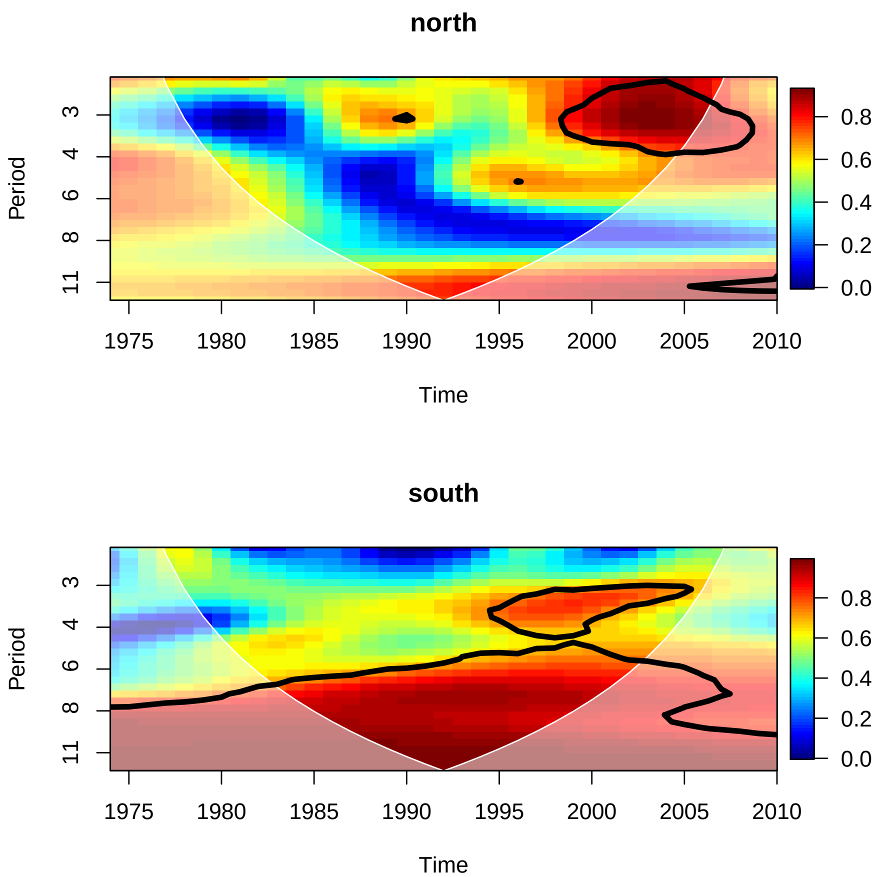

Figure 5: Wavelet coherency between signals of tree-ring widths and standardized precipitation indexes. The colored scale indicate the correlation between the two time series.