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Cuatro siglos de variabilidad hidroclimática en el noroeste de Chihuahua, México, reconstruida con anillos de árboles

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Resumen. En el noroeste de Chihuahua, sitio Mesa de las Guacamayas, catalogada como "Área Natural Protegida" (ANP) para anidamiento de la cotorra serrana, se desarrolló una serie dendrocronológica con abeto Douglas (*Pseudotsuga menziesii*) con una extensión de 409 años (1600-2008). La cronología de anillo total mostró asociaciones significativas (r>0.40, p=0.000) con cronologías vecinas (no separadas más de 200 km), particularmente las ubicadas en la misma vertiente de la Sierra Madre Occidental (SMO), lo que implica la influencia de patrones climáticos comunes, cuyos frentes húmedos impactan simultáneamente una extensa área del noroeste de México. Un análisis espectral de potencia indicó que los índices dendrocronológicos estuvieron afectados por ENSO y por otros patrones circulatorios, como se deduce de los picos espectrales dominantes (<10 años) presentes en la cronología; también mostraron asociación significativa (r=0.52, n=111, p<0.000) con registros del PDSI para el suroeste de los Estados Unidos. Una reconstrucción de precipitación acumulada enero-julio para la misma región, mostró sequías prolongadas en los periodos 1772-1782, 1793-1803, 1999-2008 y periodos húmedos en 1742-1751 y 1809-1818. La proporción de años secos detectados en la reconstrucción, sugiere que existe 50% de probabilidad de su ocurrencia a nivel anual.

Palabras clave: *Pseudotsuga menziesii*, dendroclimatología, ENSO, PDSI, noroeste de Chihuahua.

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Four centuries of reconstructed hydroclimatic variability for Northwestern Chihuahua, Mexico, based on tree rings

Abstract. A Douglas-fir chronology with a length of 409 years (1600-2008) was developed for northwestern Chihuahua in Mesa de las Guacamayas, a "Natural Protected Area" known as an important nesting habitat for the thick-billed parrot (*Rhynchopsitta pachyrhyncha*) an endangered neotropical bird. Increment cores and cross-sections from selected Douglas-fir trees (*Pseudotsuga menziesii*) in a mixed conifer forest were obtained with an increment borer and a chain-saw. Standard dendrochronological techniques were used to process and date each one of the rings to their exact year of formation. The quality of dating of the measured series was analyzed with the COFECHA program, while biological trends not related to climate (age differences, stem-size increases, and disturbances) were removed by standardization procedures in the ARSTAN program. Tree ring series of earlywood, latewood and total ring width were developed for the last four centuries. The total ring-width chronology was significantly associated (r>0.40, p=0.000) with nearby chronologies, particularly those located <200 km apart along the western slopes of the Sierra Madre Occidental (SMO) observing correlations as high as 0.69 (p<0.001). Association between chronologies decreased for those sites in the state of Durango along the SMO but separated more than 200 km in straight line and also for sites in nearby borderline in the USA side. The similar climatic response among distant chronologies implies the influence of common atmospheric circulatory patterns affecting a large portion of land simultaneously. ENSO is one of the most important factors in determining inter-annual and multiannual hydroclimatic variability in northern Mexico, increasing winter-spring precipitation in its warm phase and causing extreme droughts in its cold phase. A negative relationship (r = -0.4, n= 106, p<0.0000) was found between average January-May Southern Oscillation Index (SOI) and earlywood indices corroborating the significant influence of ENSO in cool season precipitation for this region. A power spectral analysis of the seasonal winter-spring precipitation reconstruction detected the presence of significant peaks (p<0.05) <10 years (5, 10 years) commonly associated to ENSO. Significant frequencies at 50 and near 100 years have also been related to the ENSO influence. 50-year frequency droughts historically have caused intense and prolonged droughts in northern and central Mexico, particularly those in the periods 1613-1617, 1666-1673, 1728-1733, 1752-1761, 1840-1845, 1862-1866, 1934-1939, 1944-1951, and 1953-1957. The ring-width index values were significantly associated (r=0.52, n=111, p<0.000) with PDSI values recorded for the Southwestern region of the USA. The PDSI integrates precipitation and temperature data and is a measure of the availability of moisture for tree growth as related to average moisture conditions. The relationship between PDSI data from Arizona and New Mexico and ring-width indices from Mesa de las Guacamayas, Chihuahua is an indication that extreme climatic events extend from the Southwestern USA to northern Chihuahua and even further down in the Durango state. This behavior highlights the importance of developing a network of three ring chronologies at basin or watershed level to have a better understanding of climate dynamics. A seasonal January-July precipitation reconstruction detected intense and prolonged droughts for the periods1772-1782, 1793-1803, and 1999-2008, where 1633 and 1954 stand out as the driest years of the reconstruction. Wet episodes were detected from 1742 to 1751 and from 1809 to 1818. Pluvials are less recorded in historical documents and tree rings are less sensible to wet episodes given that much of the precipitation for this region takes place in the summer months when earlywood formation that makes most of the ring size has ceased. In addition, much of the rain is lost by runoff as its intensity exceeds soil infiltration rate and water holding capacity of the soil is overridden. Historical droughts have had a severe impact in food production, reducing grain availability, increasing livestock mortality, and producing famine. The drought documented for the period 1613 to 1626 has been detected in Durango, Chihuahua and New Mexico. Later droughts like one in the 1720´s, end of the 1730´s and early part of the 1740´s produced grain scarcity and famine in a great portion of northern Mexico. The drought of the 1950´s extended all over northern Mexico and southwestern USA producing economical crisis in rural areas and greatly increased immigration and movement of migrant farm workers (braceros) to the USA. The proportion of dry years detected in the reconstruction suggests a 50% probability of occurrence of below average precipitation for a given year, implying that the development of a more extensive network of climate sensitive tree-ring chronologies will allow us a better understanding of climate variability in this region which is important for the management of limited water resources and for the conservation of endangered wildlife species.

Key words: *Pseudotsuga menziesii*, dendroclimatology, ENSO, PDSI, northwestern Chihuahua.