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Annual Growth Bands in *Hymenaea courbaril*

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Summary

One significant source of annual temperature and precipitation data arises from the regular annual secondary growth rings of trees. Several tropical tree species are observed to form regular growth bands that may or may not form annually. Such growth was observed in one stem disk of the tropical legume *Hymenaea courbaril* near the area of David, Panama. In comparison to annual reference $\Delta^{14}C$ values from wood and air, the $\Delta^{14}C$ values from the secondary growth rings formed by *H. courbaril* were determined to be annual in nature in this one stem disk specimen. During this study, *H. courbaril* was also observed to translocate recently produced photosynthate into older growth rings as sapwood is converted to heartwood. This process alters the overall $\Delta^{14}C$ values of these transitional growth rings as cellulose with a higher $\Delta^{14}C$ content is translocated into growth rings with a relatively lower $\Delta^{14}C$ content. Once the annual nature of these growth rings is established, further stable isotope analyses on *H. courbaril* material in other studies may help to complete gaps in the understanding of short and of long term global climate patterns.

Introduction

The intimate coupling of the tropical surface ocean and the overlying atmospheric boundary layer implicitly links variations in atmospheric characteristics to the underlying sea surface temperature (SST) field and local heating. Warm ocean waters provide latent and sensible heat to the atmosphere, which localizes convection and drives surface convergent winds. Convection exports moisture, which eventually precipitates out providing a freshwater source to the surface and a warming and drying of the atmosphere. The Amazon basin, southeast Africa, and Indonesia and the western tropical Pacific play important roles in the localization of deep atmospheric convective activity. The tropics as a whole are a major exporter of latent and sensible heat to both hemispheres. On interannual (e. g. El Nino-Southern Oscillation, Atlantic dipole) and longer-timescales, the export of sensible and latent heat out of the convective regions is linked to global climate through atmospheric teleconnections. Thus, variations in tropical ocean-atmosphere interactions have the capability to orchestrate worldwide climate variability over a range of timescales.

Instrumental records of key environmental variables such as temperature and precipitation are necessary to understand climate patterns and variability. In general, such observations from the tropics do not exist prior to the late 19^{th} century, and existing records contain large special and temporal gaps and are sparsely distributed. An important source of annual temperature and precipitation data comes from the regular annual growth rings of wood formed by trees. Tree growth rings occur in response to periodic seasonal changes in the environment (eg Jacoby, 1989). Although expansive and diverse in numbers and ecology, a vast majority of tropical trees do not produce distinct annual growth rings. Because of this, tropical dendrochronology and paleoclimate reconstructions have lagged behind their temperate and higher latitude cousins. However, some tropical tree species form growth bands, which could potentially be sources of data for climate studies if these growth bands form annually. For example, teak (*Tectona grandis)* and mountain pine (*Pinus kesiya* and *Pinus merkusii*) found in areas of Indonesia and Thailand have been shown to produce annual rings that relate to monsoonal climate and ENSO variations (e. g. Buckley et al. 1995, D'Arrigo et al. 1994 & 1997, Stahle et al. 1998).

Hymenaea courbaril is a large hardwood tree within the legume family Fabaceae. This species is widespread in Central and South America, with related species in Madagascar and Africa (Lewis, 1987). These trees display some form of lateral banded growth. The Panama area experiences a yearly dry season that may induce annual growth rings in *H. courbaril*. One stem disk from one *H. courbaril* tree harvested from this country in 1997 was observed to form regular lateral growth bands (Fig. 1). In order to determine the annual nature of these lateral bands, radiocarbon (^{14}C) analyses were performed on each lateral increment zone of this stem disk and compared to atmospheric ^{14}C data to determine if the growth bands formed by this tropical species were annual in nature. If the bands in this tree species are confirmed to be annual, it may be possible to use it along with related species in multi-proxy climate reconstructions.

Materials and Methods

A stem disk *Hymenaea courbaril* felled in September 1997 was obtained from colleagues Paul Colinvaux and Eduardo Montenegro. This single specimen was felled near the city of David, Panama (8º 26' N, 82º 26'W). Initial visual inspection indicated that this stem disk of *H. courbaril* consisted of 51 increment zones. Bands that maintained circuitry were assumed to be true annual growth bands and were given a year relative to when the tree was felled following the 1997 growing season. Samples of wood were taken from each increment zone and treated with a modified deVries treatment of alternate acid and base treatments of 1N HCl and 1N NaOH at 90°C, followed by repeated rinsing with deionized (Milli-Q) water to remove wood lignins (Hoper et al. 1998). Approximately 2.5mg of pretreated wood for each sample was combusted with CuO and Ag to form CO_2 gas in an evacuated and sealed quartz test tube. CO_2 from each combusted sample was reduced to elemental carbon in the form of graphite with H_2 gas in the presence of Fe catalyst (Vogel 1989). $\Delta^{14}C$ values were determined for each graphite target at the Center for AMS, LLNL (Davis et al. 1990) and were reported in accordance with Stuiver and Polach (1977). The $\Delta^{14}C$ reported values include a background subtraction determined from ^{14}C free coal and a $\delta^{13}C$ correction. To present a more representative comparison with atmospheric $\Delta^{14}C$ data, the tree ring data are presented as age corrected described in Stuiver and Polach (1977). In order to assess chemical pretreatments, a small subset of samples were processed to holocellulose with an additional acid-bleach pretreatment prior to graphitization and were then compared to $\Delta^{14}C$ data of the same increment zones receiving only the standard acid and base pretreatment.

Results

$\Delta^{14}C$ values were determined for each wood increment zone of *H. courbaril*, with each increment zone assumed to represent the growth during one year (Fig. 2). The $\Delta^{14}C$ values form a distinct curve with an amplitude of ~550‰. The maximum $\Delta^{14}C$ value is ~650‰ at the increment zone representing the 1967 growing season. The minimum $\Delta^{14}C$ value is 106‰ which occurred in the last growth increment zone representing the 1997 growing season. A small and distinct peak in the $\Delta^{14}C$ values occurs in the increment zones that represent growth in years in the late 1950s.

Discussions

The $\Delta^{14}C$ values of *H. courbaril* were compared to $\Delta^{14}C$ values of atmospheric CO_2 samples from Wellington New Zealand (Manning and Melhuish, 1994), Vermunt/Schaunisland Germany (Levin et al., 1994), and tree-ring based measurements from Olympic Peninsula firs (Stuiver and Quay, 1981). Aboveground nuclear bomb testing in the Northern Hemisphere in the late 1950s and early 1960s created a spike in atmospheric ^{14}C. ^{14}C in the atmosphere in the form of CO_2 is taken up and incorporated into wood cellulose in plants through photosynthesis. The elevated $\Delta^{14}C$ values observed in wood increment zones were a result of the incorporation of elevated ^{14}C levels in atmospheric CO_2 during this time. It is expected that the tree ring based record will bear more of a resemblance to the southern hemisphere atmospheric record due to the migration of the intertropical convergence zone (ITCZ) and the intense recycling of air masses associated with convection. In comparing wood samples of *H. courbaril* to the reference data, the similarity of $\Delta^{14}C$ values of the two data sets suggest that *H. courbaril* forms lateral growth rings that are annual in nature.

H. courbaril $\Delta^{14}C$ values form a small and distinct elevated spike in the late 1950s that does not correspond to the $\Delta^{14}C$ values of some of the reference data. This variation is most likely due to the translocation of photosynthate from younger wood having a higher $\Delta^{14}C$ content into older growth rings as sapwood is converted to heartwood. A similar observation was made by Worbes and Junk regarding the $\Delta^{14}C$ values of wood from trees in Costa Rica and Venezuela (1989). Many trees translocate photosynthate from the cambial region to interior growth bands where it is stored for later use as resinous compounds. Incomplete removal of these compounds during wood pretreatment leads to a compromised carbon isotopic record when there is a large $\Delta^{14}C$ difference between the respective years. This trend has been extensively observed in $\delta^{13}C$ studies of oak (*Quercus*) and cedar (*Librocedrus*) (Hoper et al., 1998 and references therein), as well as in the study of Worbes and Junk (1989). Chemical pretreatments can be used to remove these compounds, resulting in a reliable tree ring α-cellulose based ^{14}C record comparable to representative air flask samples (e. g. Stuiver and Quay, 1981). In this study, samples from the late 1950s that were converted to holocellulose had lower $\Delta^{14}C$ values that were more representative of the atmosphere reference records.

Conclusions

In comparison with the $\Delta^{14}C$ values of wood increment zones in *H. courbaril* with $\Delta^{14}C$ reference values of known annual nature, this stem disk of *H. courbaril* appears to form annual lateral growth rings. The formation of this annual growth is likely due to annual wood dormancy induced by a seasonal yearly dry season in the Panama area. Only one stem disk of *H. courbaril* was examined in this study. In order to confirm a consistent annual growth ring pattern within this tropical hardwood species, similar analyses of additional *H. courbaril* specimens must be completed. Once the annual nature of *H. courbaril* lateral growth bands is confirmed, its $\Delta^{14}C$ record may be cross referenced with similar *H. courbaril* wood samples from different tropical regions in order to assess any $\Delta^{14}C$ value differences that are induced by environmental differences.

H. courbaril trees and other related plant species are widespread throughout various tropical regions of the world. If *H. courbaril* and related species of the genus *Hymenaea* are proved to form annual growth rings in multiple tropical environments, increment wood samples may be analyzed for various stable isotopes to be used in other climate and paleoclimate studies. These data help to fill spatial and temporal gaps in the climate record that is necessary in understanding short and long term global climate patterns and variability.

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Figure Captions

Fig. 1. Cross section of a specimen of *H. courbaril* felled in the fall of 1997 near David, Panama (43.2 x 35.6 cm nominal elliptical axis dimensions). The visible density variations are consistent with the bands being delimited by parenchyma tissue.

Fig. 2. $\Delta^{14}C$ data of *H. courbaril* increment zones compared to the reference $\Delta^{14}C$ data of wood and air samples of known annual origin. Closed circles represent data from *H. courbaril* material pretreated with the deVries method, and open circles represent data from *H. courbaril* material pretreated with an additional acid-bleach treatment to holocellulose. Air flask data are from Europe (Levin et al., 1994), and Wellington (Manning and Mellhuish, 1994). Pre-bomb tree-ring data are from Stuiver and Quay (1981).

Fig. 1.

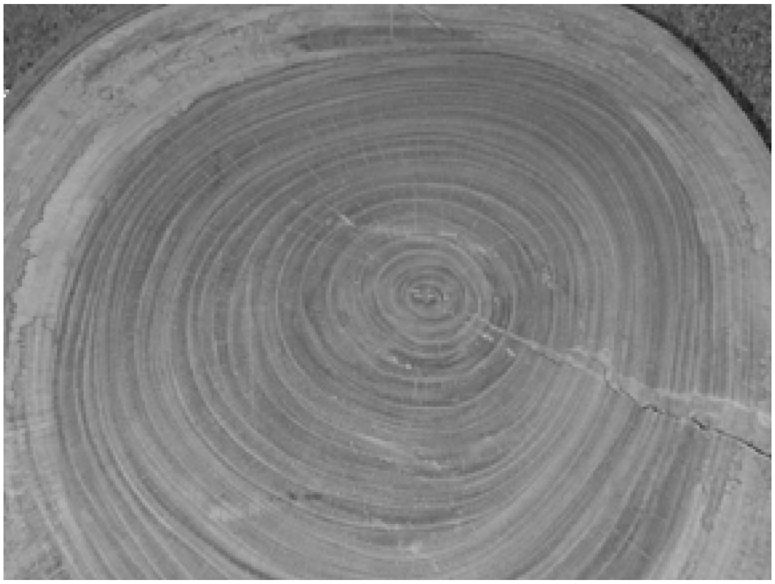
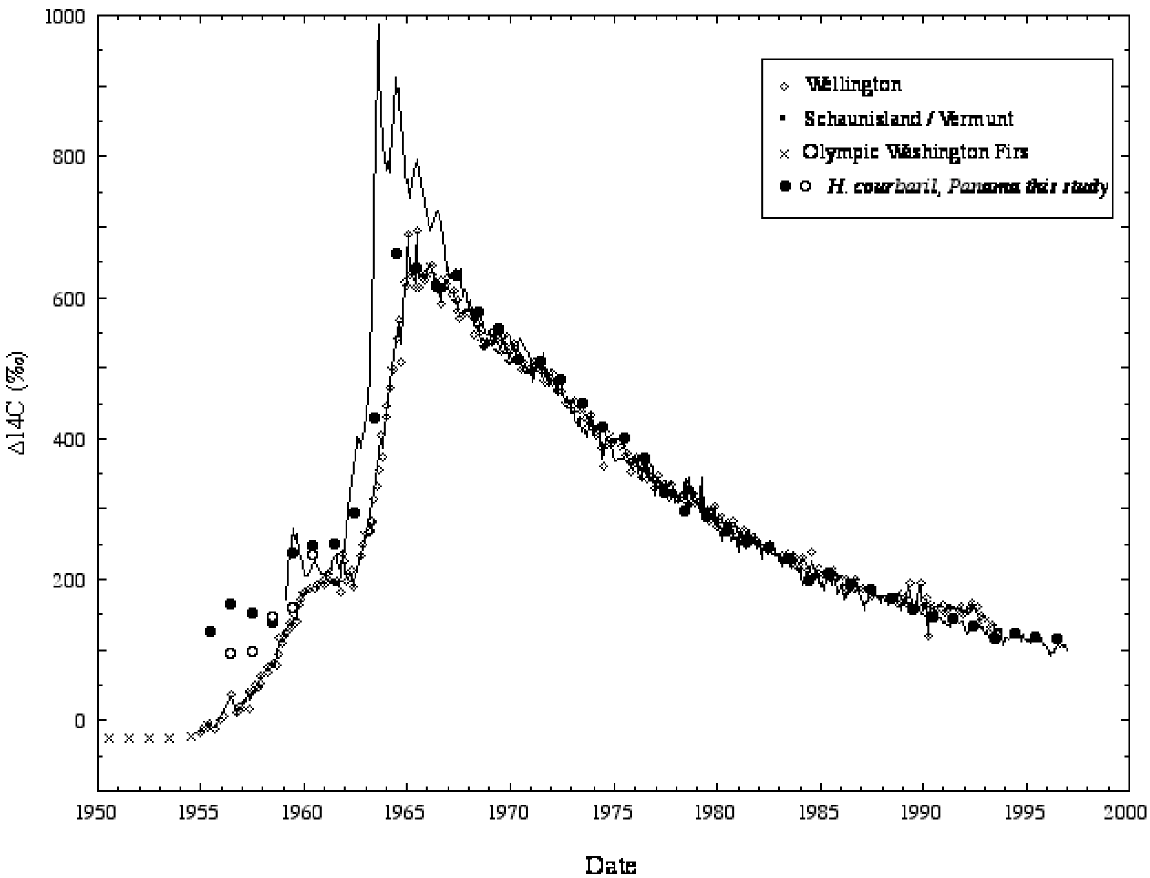


Fig. 2



Wellington
Schauinsland / Vermunt
Olympic Washington Firs
H. courbaril, Panama this study
Δ14C (‰)
Date
1000
800
600
400
200
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000