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Detecting annual growth rhythms from high-frequency densitometry and carbon isotopes in tropical mountain rain forest trees in southern Ecuador

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Introduction

Dendroclimatological investigations in temperate and northern climate zones are commonly based on the tree-ring parameters ring width and maximum latewood density. While dendroclimatology contributed significantly to our knowledge of past climate variability in higher latitudes, only sparse information has been gained by dendroecological studies in tropical regions so far. Due to the lack of pronounced climatic seasonality, trees in the inner tropics usually do not form distinct annual growth boundaries and this often hampers tree-ring analyses using ring width. To derive information about past climate variability in the humid tropics, we applied a combination of different methodological approaches, namely isotope analysis and high-frequency densitometry. This study is part of a comprehensive ecosystem research project about a tropical mountain rain forest in southern Ecuador (Beck & Müller-Hohenstein 2001).

Study area

The location of the study site “El Bosque” is near the equator at 4°S latitude in the province of Loja (southern Ecuador). It is a protected area near the Podocarpus National Park at the western slope of the eastern Andean Range (Cordillera Real) in an altitude of 2200 m a.s.l. The nearby crest line reaches up to more than 3500 m a.s.l., whereas some kilometres to the west the basin of Vilcabamba descends to 1530 m a.s.l. The climatic situation is characterized by a strong horizontal and altitudinal gradient of humidity. In austral winter “El Bosque” is in a leeward position of the Andes and a period of reduced rainfall occurs from July to September. After Richter (2003), the calculated number of humid months per year is 8–10 months at the study site. Precipitation has to be estimated, as the only nearby weather station is just running for a short period of time. Annual precipitation varies from 7000-8000 mm at the crest line to 1200 mm in an altitude of 1970 m a.s.l. near Vilcabamba (Emck 2007). For ”El Bosque”, we estimate the annual amount of rainfall between 1200-2000 mm. Annual mean temperature is ca. 15°C with a daily temperature amplitude from 10-25 °C. The samples where taken with an increment borer in September 2006 and March 2007.

Methods

Approach

Earlier investigations in this project showed that some tree species react on seasonal climate variability by forming visible density variations and growth boundaries (Bräuning & Burchardt 2006; Volland-Voigt 2006). For this study we used the conifer *Prumnopitys montana* (Podocarpaceae) that shows visible density variations. The tree diameters of up to 1m and the slow growth rates (Bräuning et al. 2008) point to potentially high living ages of several centuries. High-frequency densitometry and the analyses of stable carbon and oxygen isotopes are used to gain information about growth rhythms and past climate variability.

High frequency densitometry

The relatively new method "High-frequency-densitometry" is used to identify density variations in the wood by utilizing its dielectric properties. A micro-electrode-probe emitting electromagnetic waves passes over a smoothed wood-sample. The receiver electrode quantifies the dispersed radiation, representing the density of wood. Wood density is determined by the growth-conditioned relationship of cellulose and other cell components, of which the cell walls are composed, to air in the cell lumens (Schinker et al. 2003, Hansen 2004). With this method it is possible to identify maximum latewood density as well as even small wood density variations, which help to identify indistinct growth boundaries.

A major advantage of this method is that it is non destructive, so that the sample can be used after measuring density for further analysis, e.g. for the analysis of stable isotopes. To achieve this, a well primed and even sample surface is essential. A synchronisation of the density curves with the isotope signals shall finally enable a detection of annual growth boundaries which is the basis for the derivation of long-term climate reconstructions.

Oxygen and carbon isotope analyses

The periodicity of the density variations in *Prumnopitys montana* is not known. Because of this and the fact, that studies on intra-annual variations on stable isotopes in wood showed "significant seasonal changes in the carbon and oxygen isotope composition" (Helle & Schleser 2004), the ^{13}C analyses were carried out on thin-sections of 70 µm thickness. Doing so, stable isotope values and density variations could be assigned to corresponding topological parts of the studied increment core. For a first test, the youngest 12 mm from each core were prepared.

The seasonal change in the prevailing wind direction (Bendix et al. 2005, Richter 2003) causes a change of the dominant moisture source, which should be reflected by intra-annual variations of the $\delta^{18}O$-signal in the wood. Crossing the Amazon catchment area, the moisture of the Atlantic is depleted in $\delta^{18}O$ on its way to the Andes. Because of this continental effect, it is possible to distinguish the origin of the precipitation water. On the other hand, the $\delta^{18}O$ -signal is influenced by the amount of rainfall (the higher the rainfall the more $\delta^{18}O$ -signal is diluted). In contrast, the intra-annual variations of $\delta^{13}C$ reflect the seasonality of water availability. By using the $\delta^{13}C$-signal it ought to be possible to verify, if changes in $\delta^{18}O$ depend on drought stress or on alterations of the atmospheric circulation. Since the slopes in the study area are very steep, no groundwater contact of the root systems is expected, so that the $\delta^{18}O$ signal of the cellulose should reflect the isotopic composition of the precipitation water taken up by the roots.

In contrast, the $\delta^{13}C$ signal should enable the detection of dry phases (which are represented by high $\delta^{13}C$ values) since the $\delta^{13}C$ discrimination mainly depends on the relative humidity of the air and the resulting opening of the stomata apertures. Analysing the $\delta^{13}C$- and the $\delta^{18}O$ –signal, it should be kept in mind, that these signals are also influenced by physiological and biochemical processes, e.g. storage effects (Helle & Schleser 2004; Kagawa et al. 2006).

Results

High-frequency-Densitometry

Prumnopitys montana wood shows visible density variations, especially in the brighter sapwood. As expected, these visible structures are reflected by the density curve (Fig.1); each peak in the density curve represents a darker density band. Further analyses have to reveal the temporal periodicity and the physiological causes of these density variations

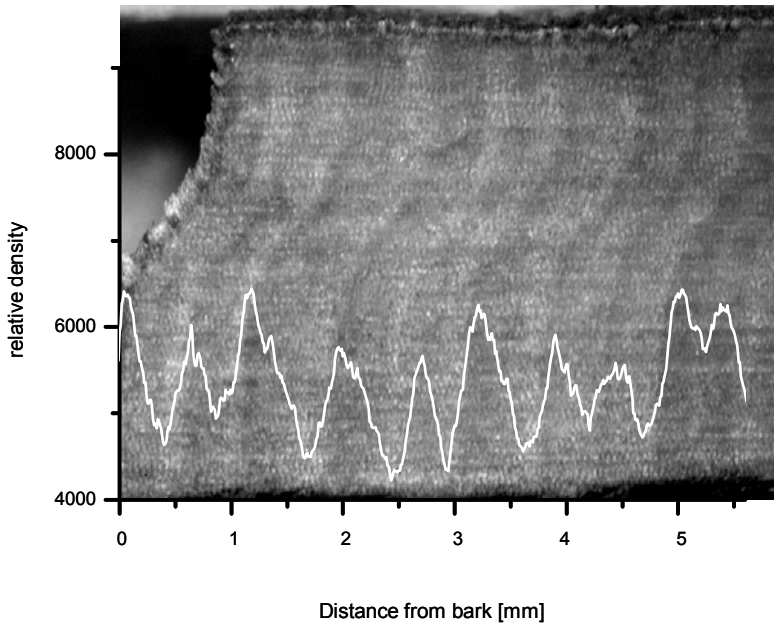

Figure 1: Relative density variations of Prumnopitys montana. The white line shows the measured density variations, whereas the background shows the corresponding part of the sample with the visible wood structures.

^{13}C Analyses

Fig. 2 shows the stable carbon isotope variations of the outermost 12 mm of the examined stems. We assume that the distinctive minima and maxima in the isotope curve (as marked by the arrows) represent wood that was formed synchronously under certain climate conditions. However, these parts of probably same formation time are situated at different distances from the bark in the various trees. This is the result of different growth rates of the studied individuals.

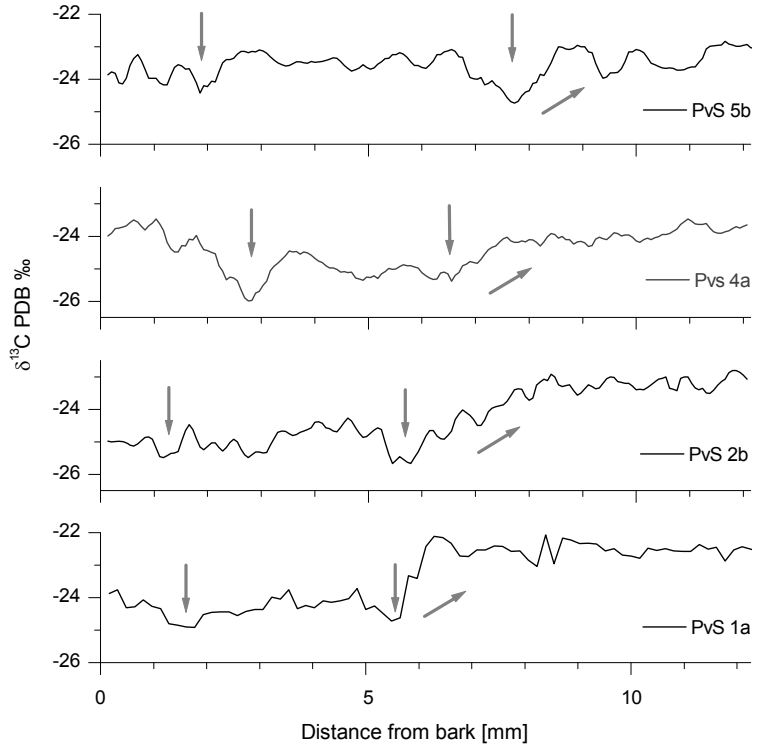

Figure 2: δ^{13}C-values from four individuals of Prumnopitys montana. The curves are smoothed by a 5 point moving average. Grey arrows indicate the occurrence of certain minima and trends in the isotopic composition which are probably caused by climatic events affecting all trees synchronously.

Conclusions and outlook

It could be seen that HF-density as well as $\delta^{13}C$ measurements show pronounced variations along the examined increment cores. In a next step we will examine if these variations can be synchronised within the same parameter and if wood density and $\delta^{13}C$ variations reflect the same seasonal patterns. At the moment, however, the available results suffer from two restrictions: First, the $\delta^{13}C$-curves are yet too short and have to be enlarged to proof accordance of isotope variations between different individuals over a longer period of time. Second, the number of studied individuals should be increased from 4 up to a minimum of 6.

Calibration studies of wood density and stable isotope composition with climate data shall be carried out separately for the two wood parameters to evaluate if there exists a causal link between density and stable carbon isotope variations. Although the applied combination of techniques is very time consuming, it seems very promising to better understand the linkage between tree growth and climate variability in tropical mountain reagions.

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