

Isotope studies along a high-elevation transect on the Tibetan Plateau

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Introduction

Besides investigations on the variability of stable isotope ratios in ice-cores and sea-sediments, corresponding studies in tree rings have demonstrated a tremendous potential for high resolution paleoclimatic reconstructions on a millennial timescale (*Anderson et al.* 1998; 2002, *Berninger et al.* 2000, *Saurer, M. & Siegenthaler, U.* 1995, *Schleser et al.* 1999). During the last years, considerable progress has been made in the development of stable isotope techniques. Thus, measuring time for samples could drastically be reduced therewith enhancing the throughput of samples considerably (*Treydte* 2002).

Until today the number of tree-ring isotope studies for paleoclimatic investigations in the climatically sensitive region of the Tibetan Plateau is still scarce. This is very much in contrast to its key role for the regional circulation systems in Asia and Africa. By generating a distinctive low pressure system during the summer months due to the heating of the plateau, warm and moist air masses from the Indian and Pacific oceans are directed across the Indian subcontinent and southeast Asia. This causes heavy summer rainfall in the Himalayas and the mountain areas of western China, known as the Indian and the East Asian summer monsoons. When the Tibetan plateau cools in winter, a high pressure system is building up, resulting in the prevalence of cold and dry air masses (*Webster et al.* 1998). This pronounced cyclicity between summer and winter climate associated with the high altitude and the extreme high mountain topography leads to a distinct regional differentiation of climate and vegetation zones in the study area.

The aims of the study are:

- (i) to establish an annually resolved tree-ring based millennial dataset of stable carbon ($\delta^{13}\text{C}$) and oxygen isotopes ($\delta^{18}\text{O}$).
- (ii) to quantify the climatic significance of the datasets.
- (iii) to investigate additional wood parameters like ring width and maximum latewood density and to use the various proxy datasets for reconstructing the variability of the monsoon during the last millennium.
- (iv) To compare the annually resolved carbon isotope chronology from Qamdo to be established with an existing isotope chronology from the same site showing a pentad resolution (*Zimmermann et al.* 1997; *Helle et al.* 2002).

Material and Methods

Site description and study material

Within this project emphasis is based on high altitude forest sites situated along a gradient of decreasing influence of summer monsoon. Thus, a transect is considered, reaching from the humid eastern margins to the dry central part of the Tibetan Plateau (figure 1). We collected wood samples of juniper (*Juniperus tibetica*) from south-facing slopes and of spruce (*Picea balfouriana*) from north-facing slopes. The aim is to compare the effect of climatological forcing factors on various tree-ring parameters like ring width, maximum latewood density and stable isotope ratios.

The biological age trend of the ring width series was removed by dividing the original data with a fitted spline function that eliminated 50% of the variance at a length of 67% of each series using the program ARSTAN. The resulting standard juniper and spruce chronologies cover the past up to 1500 years and 400 years, respectively.

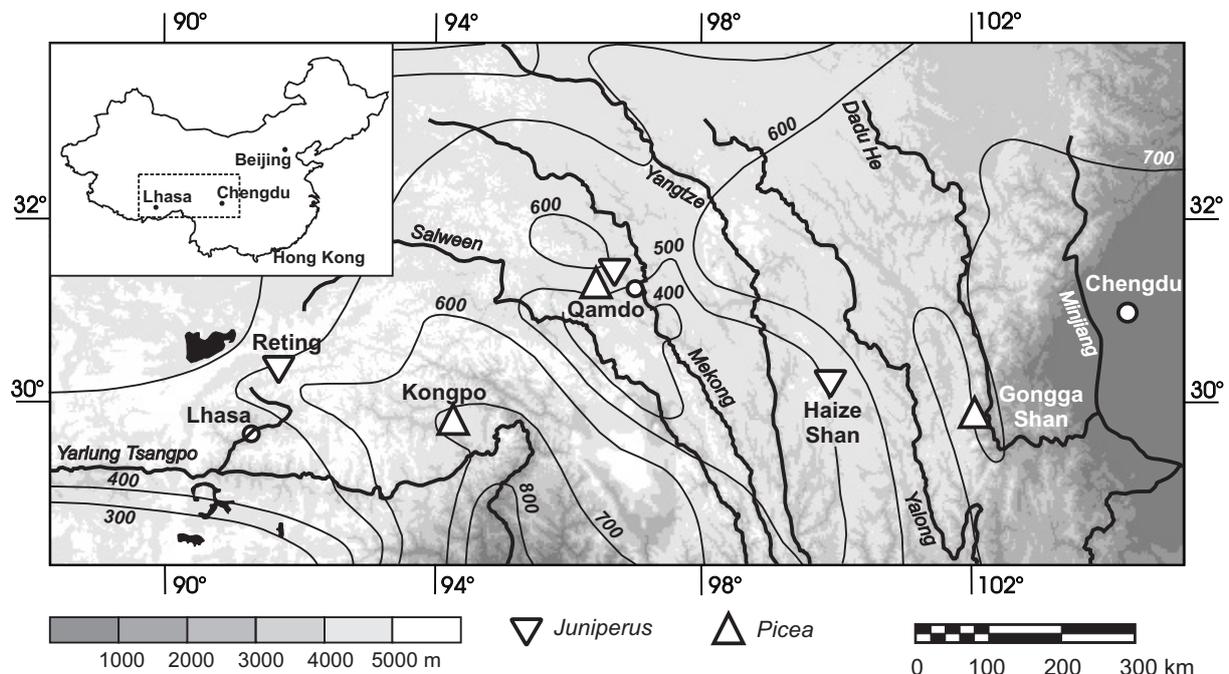


Figure 1: Overview of the investigation area and position of the sampling sites at the Tibetan Plateau. Isolines show mean annual precipitation in mm.

In table 1, several characteristics of the currently available ring width chronologies are summarized except for the site chronology 'Gongga Shan' which is still under investigation. Although exceptions occur, the signal-to-noise ratio (SNR; Wigley *et al.* 1984) and mean correlation between the trees (\bar{r}) generally increase in the direction from humid to dry sites, whereas first-order autocorrelation (AC1) shows a reverse trend.

Table 1: Characteristics of eastern Tibetan ARSTAN STD ring width chronologies. Relatively dry sites are marked in white columns, medium sites are highlighted in light grey, humid sites in dark grey.

Site	Reting	Qamdo	Haize Shan	Kongpo	Qamdo
Tree species	<i>Juniperus tibetica</i>	<i>Juniperus tibetica</i>	<i>Juniperus tibetica</i>	<i>Picea balfouriana</i>	<i>Picea balfouriana</i>
Site elevation	4300 m	4450 m	4400 m	ca. 4100 m	4500 m
Chronology	1082-1999	445-2003	1174-1993	1635-1998	1406-2003
Length (years)	918	1559	820	366	598
average tree age	475	597	558	281	278
max. tree age	917	1306	819	364	589
No. of trees	40	34	8	12	22
SNR	8.97	3.14	1.16	2.02	8.96
AC1	0.38	0.42	0.67	0.50	0.75
rbar	0.31	0.18	0.28	0.16	0.36

In a first phase, 4 cores and 6 tree disks from a Juniper stand (*Juniperus tibetica*) were analyzed. The samples were collected at a south-facing slope near the upper timberline (~ 4500m a.s.l.) in the south-eastern part of Tibet close to the city of Qamdo (compare fig. 1). Each tree sample was crossdated against an existing ring width chronology (Bräuning 2002) using the TSAP™ program. In order to develop a millennial scaled carbon isotope record from the Qamdo site, tree disks and core samples from living and dead trees were combined. After exact dating, the individual tree-rings were cut using a razorblade. Wood samples of corresponding age were then pooled to minimize the possible influence of outliers caused by potential ecological differences between the individual trees (Borella and Leuenberger 1998).

Cellulose extraction and mass spectrometry

Since wood material consists of different chemical components with rather different isotope signatures ($\delta^{13}\text{C}$), it is necessary to concentrate on one single chemical compound. It is usual practice to extract cellulose for carbon isotope analysis because it is easiest to obtain. To extract cellulose the separated samples were treated in small glass vials at 60°C using a water bath. The corresponding technique is described by Kürschner and Popik (1962). In a first step, lignin, resins and other components were removed with NaOH (treatment for about 4 hours). Then, hemicelluloses were extracted for 36 hours with slightly acidified NaClO₂. Between these two steps, the wood samples were washed several times with deionized water. After the cellulose extraction the samples were dried at 60°C for about 48h until they reached weight constancy. Subsequently, the pooled specimens were milled using a cryogenic mill to attain homogeneity between the constituents of the different trees. These annual cellulose samples were weighted to achieve aliquots of 200µg/sample and then packed into tin capsules for carbon isotope analysis. Samples were then combusted to CO₂ using an on-line method with an elemental analyzer (Carlo Erba) interfaced to a mass spectrometer (Micromass Optima) where the analyzed $\delta^{13}\text{C}$ values are automatically scaled against the Vienna standard of PDB (V_{PDB}).

Results

As a first result, an annually resolved 500-year $\delta^{13}\text{C}$ -isotope record from *Juniperus tibetica* trees originating from Qamdo was established. As Fig. 2 shows, clearly recognizable shifts in the values of $\delta^{13}\text{C}$ occurred during this period. Although statistical analyses have still to be carried out, several outstanding features like the double peak between 1550 and 1630 are obvious. Former analyses have shown a statistically significant response of ring width of juniper at the Qamdo site to winter temperature and summer rainfall (Bräuning 2002), whereas interannual $\delta^{13}\text{C}$ variations are positively correlated with summer temperature (Helle *et al.* 2002). To eliminate the anthropogenic "fossil fuel burning effect" of an increasing atmospheric CO_2 trend combined with a depletion of its ^{13}C fraction (Fig.2), a correction of the measured $\delta^{13}\text{C}$ values since 1850 had to be performed (Feng and Epstein 1995). We used two different CO_2 correction models (Fig. 2). The $\text{CO}_{2\text{ATM}}$ model corrects the measured $\delta^{13}\text{C}$ raw data by adding a variable factor derived from atmospheric $^{13}\text{CO}_2$ datasets of meteorological stations and ice cores. In addition, the model by Feng and Epstein ($\text{CO}_{2\text{FENG}}$) also allows for plantphysiological corrections of the carbon isotope signature which experiences a shift to more depleted values due to the atmospheric CO_2 increase. Fig.2 shows the generally observed declining trend in the curve of $\delta^{13}\text{C}_{\text{raw data}}$ which still remains for the $\delta^{13}\text{C}_{\text{ATM}}$ curve. A slightly increasing trend is seen for the $\delta^{13}\text{C}_{\text{FENG}}$ record. Which correction model finally will be applied is uncertain which makes the interpretation of the last part of the record difficult.

Due to the high tree ages of the juniper trees (Table 1), the final isotope series from Qamdo will reach back to 445 AD and thus will cover climatically important periods like the so-called "Little Ice Age" and the "Medieval Warm Period". The latter can be regarded as climatically equivalent to the temperature conditions that are predicted by global circulation model results for the near future (Ni 2000; Uchijima & Ohta 1996).

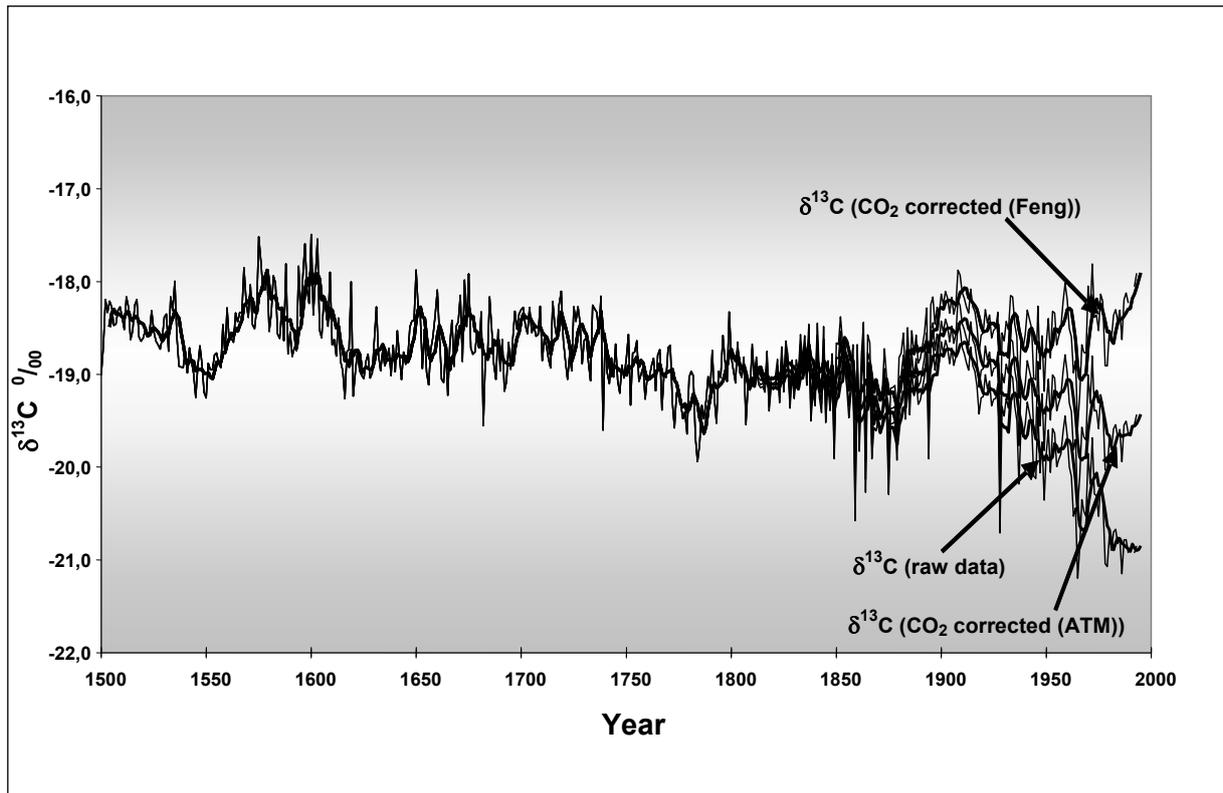


Figure 2: Yearly resolved ^{13}C -isotope record (against V_{PDB} standard) deduced from juniper trees originating from Qamdo, Tibet. The record is based on 5 pooled trees, each of them covering the whole study period. For further explanations of the shown CO_2 trends after 1850, see text.

Wood parameters, like maximum latewood density (MLD) and variations of $\delta^{18}\text{O}$ shall be analysed in the near future for all sites and compared to regional meteorological datasets. By using this multiproxy approach for ecologically contrasting tree species along a broad scale precipitation gradient we expect to gain new insights into the temporal and spatial patterns of climate variability in the marginal areas of the monsoon realm on the Tibetan Plateau.

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