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The development of a long pine (*Pinus wallichiana*) chronology from western Nepal from living trees and ^{14}C-dated historic wood samples

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Introduction

Western Nepal is a remote mountainous region in the central Himalaya that has been poorly studied by means of dendrochronology so far (Bhattacharyya 1992; Cook et al. 2003, 2010, Bräuning 2004). The Dolpo district is located in the inner Himalaya north of the Himalayan crest line and is therefore located in the relatively dry lee side of the Indian Summer Monsoon. *Pinus wallichiana* is one of the dominating tree species in higher elevations and has widely been used for constructing purposes. In the neighbouring Upper Mustang area farther to the east, pine tree-ring series collected from historic settlements have been successfully crossdated to chronologies from living trees, resulting in a chronology spanning almost 700 years (A. D. 1303-1996) (Schmidt 1993; Schmidt et al. 1999, 2001; Gutschow 1994; Gutschow et al. 2001).
Bräuning et al. (2004) had constructed a chronology of living *P. wallichiana* samples from relict sites in the upper Dolpo region (82°54' E, 29°26' N; 3850 m a.s.l.) spanning a 443-year period from A. D. 1556-1998. In addition to the living trees, increment cores from timber of historic Buddhist monasteries were collected. However, although younger historic material could be successfully dated (Bräuning 2004), we were unable to synchronize other historic wood samples, even though they contained a sufficient number of tree rings. Preliminary climate-growth analysis indicated ring-width variations of *P. wallichiana* to correlate to precipitation during the summer monsoon season (April to September) (Bräuning 2004). Thus, we tried to extend our existing pine chronology into the past by means of radiocarbon analysis to reconstruct precipitation variations during climate episodes of particular interest like the medieval warm period.

Material and Methods

Historic samples of *P. wallichiana* from four monasteries, Lang Gompa (three samples), Nesar Gompa (two samples), Samling Gompa (two samples) and Tsakhang Gompa (two samples), were collected. Tree species had been determined by anatomical means. Width of the historic tree-ring material was measured on a LINTAB II measuring system (Rinntech, Heidelberg, Germany). We applied AMS age determinations in the Erlangen radiocarbon laboratory to tree-ring series that could not be crossdated to the existing chronology either due to the shortness of the sequences or due to an age older than the chronology. As generally known, individual radiocarbon dates yield multiple results and do not allow straightforward dating due to variations in the radiocarbon calibration curve. However, by defined age differences (e.g. by counting tree-ring numbers) of several consecutive radiocarbon samples it is possible to match the radiocarbon ages of these samples to the 'wiggles' of the radiocarbon calibration curve. This so-called wiggle match technique permits to constrain the probability distribution of the calibrated radiocarbon result and to exclude those dating intervals that become extremely unlikely. The wiggle matched ages for this study were calculated at the 68.3% confidence limit using the D_SEQUENCE function of the radiocarbon calibration program Oxcal 3.10 (Bronk Ramsey et al. 2001) with INTCAL04 (Reimer et al. 2004) as calibration curve.

Results and discussion

In total, 25 AMS-ages from nine wood samples were measured. An example of a successful wiggle match dating is shown for sample NLG4_8 from Lang Gompa, where a normal calendar age calibration (calibration also by Oxcal 3.10 using INTCAL04) of three ^{14}C-samples revealed multiple results that nearly cover the whole time interval from 1650 AD to 1950 AD (Table 1). By applying the wiggle matching method the possible calendar age intervals could be considerably constrained. A dating check with the Dolpo chronology at the suggested AMS-age position resulted in a probable dendrochronological position of the sample. Nevertheless, the test statistics are not very strong (sign-test 68% [p<0.01]; t-test after Holstein: 2.7; t-test after Bailie/Pilcher: 1.9, Figure 1), which is probably related to individual disturbance signals in the sample.

Table 1: AMS ^{14}C dating results for samples from monastery Lang Gompa (Dolpo region, Nepal)

Lab code	Sample Name	BP	$\delta^{13}C$	Cal AD (1 σ) without Wiggle Matching	Cal AD (1 σ) with Wiggle Matching
Erl-13059	NLG4_8, rings 1-4	145 ± 40	-21.1	1673 AD - 1697 AD (10.2%) 1725 AD - 1778 AD (23.0%) 1799 AD - 1814 AD (6.7%) 1835 AD - 1877 AD (16.9%) 1917 AD - 1942 AD (11.4%)	1678 AD - 1695 AD (17.4%) 1719 AD - 1738 AD (34.6%) 1879 AD - 1892 AD (16.2%)
Erl-13060	NLG4_8, ring 31	123 ± 40	-20.5	1683 AD - 1735 AD (20.9%) 1805 AD - 1891 AD (37.8%) 1908 AD - 1930 AD (9.4%)	1708 AD - 1725 AD (17.4%) 1749 AD - 1768 AD (34.6%) 1909 AD - 1922 AD (16.2%)
Erl-13061	NLG4_8, rings 62-63	223 ± 40	-21.5	1644 AD - 1680 AD (29.9%) **1764 AD - 1800 AD (28.3%)** 1939 AD - 1953 AD (10.0%)	1739 AD - 1756 AD (17.4%) **1780 AD - 1799 AD (34.6%)** 1940 AD - 1953 AD (16.2%)

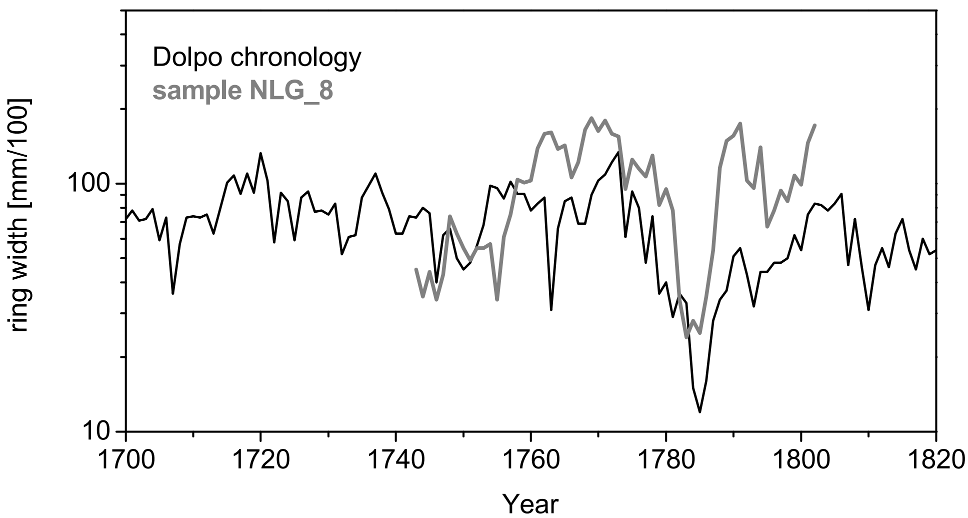

Figure 1: Curve of sample NLG4_8 displayed against the Dolpo chronology at the position suggested by the wiggle-matching procedure A.D. 1743-1804.

The present state of chronology development for the Dolpo area is shown in Fig. 2. It consists of Dolpo chronology (living trees) spanning 443, years back to 1556 AD as well as floating tree-ring series dated by radiocarbon. Some samples date back into the 7th century A.D. and are to our knowledge the oldest tree-ring samples collected in western Nepal.

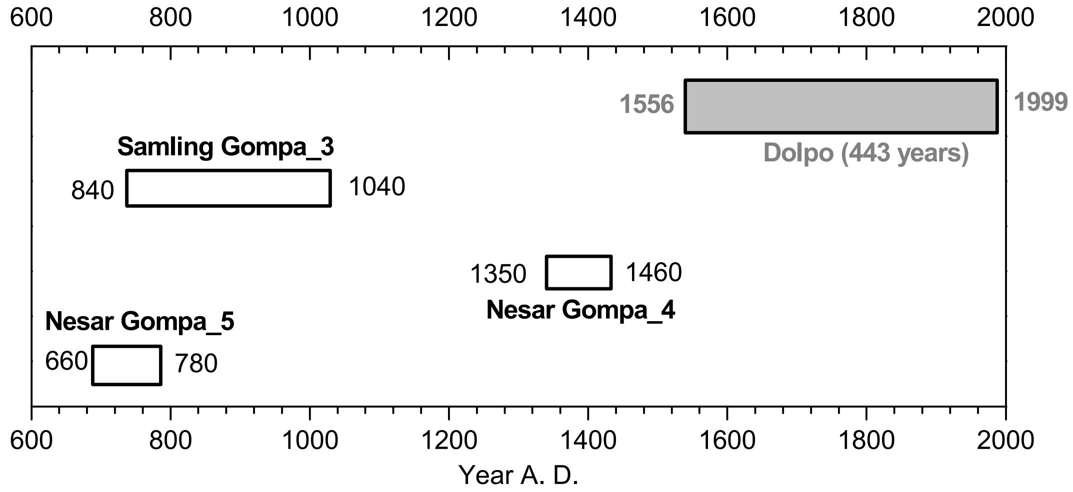

Figure 2: Length of the existing Dolpo pine chronology from living trees (grey bar) and dates of floating ^{14}C-dated historical wood samples collected from different monasteries (empty bars).

Conclusions

The first results of our study demonstrate the potential of radiocarbon wiggle-match dating applied upon historic tree-ring material. Collecting and dating additional pine samples from historic objects (e. g. Schmidt et al. 1999, 2001; Gutschow 2001) may lead to a tree-ring chronology spanning more than a millennium. It might also replenish the very limited palaeoclimatic information from this vulnerable high mountain region (Cook et al. 2003, 2010). An existing gap of precipitation-sensitive tree-ring sites between western Himalaya and Karakorum (Esper et al., Treydte et al. 2006) and the central Tibetan plateau could be closed as well. Furthermore a closing of the yet existing gaps in the chronology may provide an important tool for dendrochronological dating of objects of great cultural value.

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