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Holocene tree-line variability in the Kauner Valley, Central Eastern Alps, indicated by dendrochronological analysis of living trees and subfossil logs

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Abstract The altitude of the Alpine tree-line has often been used as proxy for the climatic conditions in the Holocene epoch. The usual approach for establishing a record for this proxy is the analysis of pollen and macro remains. We analysed living trees and subfossil logs from the timberline ecotone in the innermost Kauner valley in the Central Eastern Alps in order to assemble a Holocene dendrochronological tree-line record. Data sets comprising age and height of living Stone Pines (*Pinus cembra* L.) were collected at one site. Sections of 170 subfossil Stone Pine logs from five other sites were dendrochronologically analysed and dated. Besides using dendrochronological analyses, radiocarbon dating served as a means of obtaining the age of some logs. For most of the samples we could provide dendrochronological dates (1-year dating precision, back to 5125 B.C.) or wiggle matched dates (between approx. 7100 and 5040 B.C., dating precision with 95% probability: ± 7 years). In the first half of the 19th century the tree-line was located at about 2180 m a.s.l. in the innermost Kauner valley. After approximately A.D. 1860 the altitude of the upper limit of the occurrence of *Pinus cembra* individuals (tree-species-line) and, being closely linked, also that of the tree-line both rose. The current tree-line (trees >2 m) is located at 2245 m a.s.l. due to climatic conditions around 1980. Additionally we observed saplings up to a present (A.D. 2000) tree-species-line at approx. 2370 m a.s.l. The dendrochronologically analysed subfossil logs found at up to 2410 m a.s.l. date from within the last 9000 years (be-

tween approx. 7100 B.C. and A.D. 1700). In the space of the last 4000 years the dendrochronological tree-line record is not continuous, probably due to human impact. Tree-line positions similar to or slightly above the 1980 tree-line are established for the time periods approx. 1000 to 640 B.C. and A.D. 1 to 330 respectively. For the time period between approx. 7100 and 2100 B.C. the dendrochronologically analysed logs show nearly continuous evidence of a tree-line above the 1980s limit. Very high elevation of the tree-line, between 120 and 165 m above the 1980s level (2245 m a.s.l.) and even higher than the A.D. 2000 tree-species-line (2370 m a.s.l.), are recorded for the periods 7090–6570, 6040–5850, 5720–5620, 5500–4370 B.C., approx. 3510–3350 B.C. and 2790–2590 B.C. Additionally, a tree-line which was located at least 50 m above the 1980s limit can be shown for the periods 6700–5430, 4920–3350 and 3280–2110 B.C. The dendrochronological record from the Kauner valley, showing high and very high tree-line positions between approx. 7100 and 2100 B.C. with only two gaps (around 6490 B.C. and from 3350 to 3280 B.C.), suggests that summer temperatures as observed in the late 20th century were at the normal or the lower limit of the temperature range which can be assumed for long periods of the early and middle Holocene epoch.

Keywords Holocene · Alps · tree line · *Pinus cembra* · dendrochronology

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Introduction

The analysis of tree-line fluctuations is a classical approach to investigating the variability of the climate during the Holocene. For many years palynological research on material found in peat bogs or lakes within the timberline ecotone has been the methodological procedure for such studies (for the Western and Southern Alps: Welten 1952; Zoller et al. 1966; Carcaillet and Thimon 1996; Burga et al. 2001; Tinner and Theurillat 2003). For the middle part of the Eastern Alps Sigmar Bortenschlager and his group at the Institute of Botany,