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Impacts of climatic extremes during MIS 3 on Alpine vegetation: evidence from Nesseltalgraben (SE Germany)

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The effects of extreme climatic changes on Alpine ecosystems during the last glacial are poorly understood. The recently discovered Nesseltalgraben site in the northern Alps provides a high-resolution sediment sequence covering the Marine Isotope Stage (MIS) 3 (59-28 ka BP), a period characterized by climatic extremes known as Dansgaard-Oeschger cycles or Greenland interstadials/stadials. The radiocarbon-dated composite profile of 21 m stratigraphic height provided a continuous pollen profile, bryophyte macrofossils, and wood remains. Additional to palaeobotanic studies, stable isotope analyses (δ^2H, δ^{13}C, δ^{18}O) of bulk sedimentary cellulose and plant macrofossils (wood, monocots, and bryophytes) complemented the palaeoenvironmental and palaeoclimatic studies. Among the terrestrial pollen, Poaceae and arboreal pollen showed an antithetic behaviour and high variability reflecting interstadial-stadial climatic switches. Arboreal pollen are dominated by *Pinus sylvestris*-type, with admixtures of *Picea*, *Betula*, *Alnus*, and *Salix*. The arboreal pollen record exhibits several maxima indicating milder climatic conditions, tentatively attributed to Greenland interstadials 5.1, 6, 8, 11/12 and 14-17. During Heinrich events 4 and 5, arboreal pollen show distinct minima underlining a severe impact of these events on regional climate and vegetation. Bryophyte assemblages show dominant wetland conditions at the site during the entire MIS 3. The sudden occurrence of *Drepanocladus turgescens* after 31.6 ka cal BP indicates a change from a fen to a frequently drying wetland habitat linked to enhanced glacifluvial action caused by glaciers approaching towards the site. Stable isotope analyses of extracted bulk sedimentary cellulose revealed strongly fluctuating values best interpreted by variable mixtures between a terrestrial end member (lignified plants, monocots) with high δ^2H, δ^{13}C, and δ^{18}O values on the one hand, and wetland (bryophyte) cellulose sources with low isotope values on the other. Strong negative isotope excursions in the sedimentary and bryophyte cellulose records between 37.3 and 34.8 ka cal BP are best explained by a change to more humid conditions, possibly related to enhanced permafrost, and are contemporaneous with massive

increases of Cyperaceae pollen. We conclude that the vegetation at Nesseltalgraben responded to several Greenland stadials/interstadials and Heinrich events. A straightforward correlation between vegetation oscillations and Greenland ice core records, as has been found in Alpine speleothem isotope records, is, however, not always obvious which could be the result of multiple additional abiotic and biotic factors influencing tree dissemination and growth.