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Using recent and historical larch wood to build a 1300-year Valais-chronology

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Introduction

To add understanding to the current 'Global-Change-debate', it is relevant to study the variability of Holocene climate (IPCC 2001). By placing the 20th-century warming in the context of long-term temperature variations, dendroclimatic reconstructions spanning the past millennium enable further analyses of the role of greenhouse gases on recent climate change.

Tree-ring chronologies are frequently used as a proxy for climate variations, because width, density, and stable-isotope measurements obtained from trees correlate with temperatures over the growing season (e.g., Fritts 1976, Schweingruber 1996, Treydte 2003). These proxy time-series provide a detailed history of changing temperatures throughout the last millennium on local, regional and even hemispheric scales (Briffa et al. 2001, Esper et al. 2002, Jones et al. 1998, Mann et al. 1999). The reconstruction of climate variations using proxy data is closely tied to the calibration of tree-ring records against observational temperature (and precipitation) data to provide estimates of the magnitude of past changes.

To extend the about two centuries long observational records from the Alps (e.g., Böhm et al. 2001) back in time, local tree-ring (or other proxy) data are needed. The development of millennia-long reconstructions is possible by combining wood from living trees with, for example relict timber from historic buildings. If such historical wood is used to develop a long chronology, information can be derived on both, historical dating and multi-centennial environmental variations. Here we show first results of building a millennial-long larch (*Larix decidua* Mill.) ring-width chronology from recent and historical wood from sites in the subalpine Lötschental and surrounding areas in the Valais (Swiss Alps). The sampled larch trees and the wood from historical buildings originate from high-elevation forests near the upper timberline, which improves the chance of finding high correlations between ring-width and growing season temperature variation - primarily June, July and August (Frank and Esper 2004). The climatic sensitivity of larch and its recurring defoliations caused by larch budmoth (*Zeiraphera diniana*) attacks (Björnstad et al. 2002, Rolland et al. 2001) support successful crossdating (Douglass 1941) and allow the absolute dating of historical timber. The recent and historical larch data were merged and standardized to preserve mid-frequency, inter-decadal variations. As a result, a new 1300-year Valais chronology was developed that can be used to study mid-frequency temperature variations in the Central Alps. Furthermore, the study might contribute to the understanding of spatio-temporal patterns of the larch budmoth outbreaks, and enable addressing the history of local settlement.

Tree-ring data

Recent and historical sampling sites were selected in the Lötschental and surrounding areas in the Valais from 7-9°E and 46-47°N. The collected larch wood originates from forest sites > 1,500 m a.s.l. The high-elevation setting of all larch wood hopefully leads to a homogenous response to temperature variations as the dominant growth-limiting factor. To extend the about 300-year long chronologies from living trees in the Lötschental, several datasets composed of historical construction wood are analyzed (table 1). The data from Simplon-Dorf developed by M. Schmidthalter lengthens the composite record back to AD 685.

Table 1: Dendrochronological data

Site location	Number of samples	Period	Mean segment length	Average series intercorrelation
Lötschental recent	90	1682-2001	223.2	*r* = 0.667
Lötschental relict	147	1168-1940	213.3	*r* = 0.608
Goms/VS relict	143	1082-1995	117.8	*r* = 0.478
Simplon-Dorf relict	26	685-1200	352.0	*r* = 0.638
Valais recent + relict	30	1200-1995	159.9	*r* = 0.510

The composite dataset is characterized by specific advantages and disadvantages. Advantages include *(i)* the well-documented metadata information, particularly for the Lötschental samples, *(ii)* the spatial homogeneity of construction wood, *(iii)* the significant segment lengths, *(iv)* the expected temperature sensitivity resulting from high-elevation origins, and *(v)* excellent crossdating characteristics. Disadvantages include *(i)* the reduced site-ecological information of construction wood, *(ii)* the frequently missing outermost rings (waney edge resp. Waldkante) on samples from construction wood, *(iii)* the frequently missing pith-offset information, and *(iv)* the defoliation caused by budmoth outbreaks affecting the high-frequency climatic signal.

Methods

Of a total of 471 samples from 60 buildings and 95 samples from living trees in the Lötschental, and of 320 series from several locations in the Valais, we use only 436 series for the development of the new chronology (figure 1). All samples were first checked for sufficient segment length and the quality of the core. Only cores with more than 60 rings and less than 5 breaks were measured. Such breaks occur frequently when collecting dry wood from historic buildings.

The measured series were then crossdated using the program COFECHA (Holmes 1999). For crossdating we standardized the ring-width series by calculating ratios from a 32-year cubic spline. This procedure reduces the amplitude of 32-year wavelength variations by 50%. COFECHA was then used as a tool to help identify missing rings and incorrect matching. Finally, a total of 237 samples from the Lötschental, and 199 series from surrounding sites were retained to build the 1300-year larch chronology.

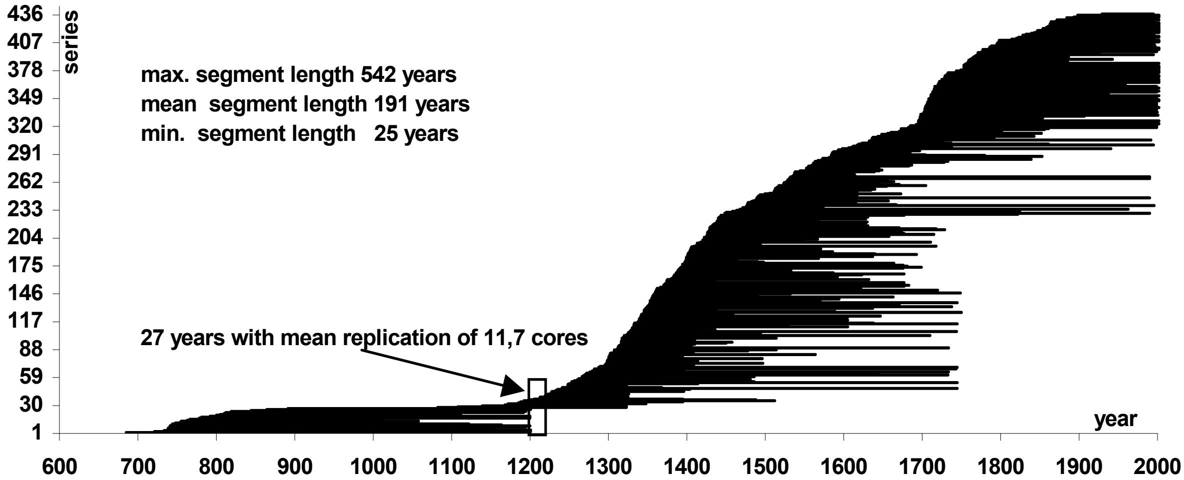

Figure 1: Segment length and dating of 436 individual larch series from the Valais.

To remove age-related noise from the data, first an adaptive power transformation was applied to the measurements to stabilize the variance (Cook and Peters 1997). The resulting homoscedastic time series were then detrended by calculating residuals from individually fitted 300-year spline functions (Cook and Peters 1981). This method eliminates any long-term growth trend and retains annual to multi-decadal variations. In total, chronologies from five independent sub-datasets were developed, using the program ARSTAN (Cook 1985). The composite of these records spans the AD 685-2000 period.

Results and Discussion

According to the outlined detrending methods, several regional chronologies emphasizing annual to inter-decadal variations were constructed (figure 2). The Schmidhalter chronology covers the longest period back to AD 685, followed by the historical chronology from the Lötschental, which runs back to AD 1168, and the three Lötschental chronologies from living trees, which run back to ca. 1700. A 31-year moving average emphasizes the decadal to multi-decadal variations.

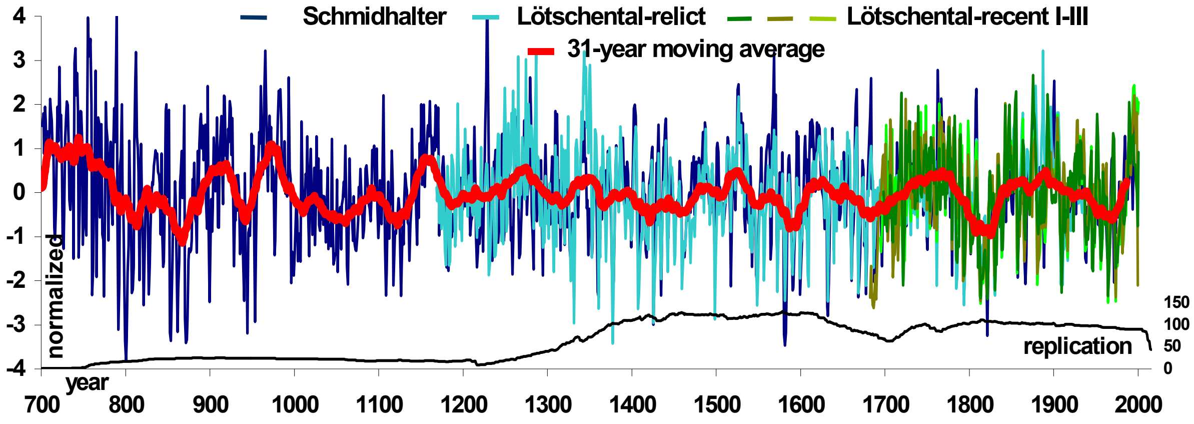

Figure 2: Five larch chronologies standardized using 300-year splines.

The individual detrending of recent and archaeological larch wood enabled the construction of well-replicated mean curves using only those ring-width series that showed a significant statistical agreement. The great mid-to-high frequency similarity of the different data sets demonstrates the potential to use the collection of relict wood from the Lötschental and surrounding sites to usefully extend the Lötschental living chronologies back in time.

To provide an overview of the historical construction wood from the Lötschental, a compilation of the numbers of collected and dated samples from each building is given in figure 3. From a total of 152 dated archaeological samples, only 91 contain sapwood. This group has an average of 26.7 sapwood rings with a minimum of 6 and a maximum of 58 sapwood rings. The mean segment length is 230 years, with a minimum of 80 and a maximum of 504. 55 samples have the waney edge, and this latter group had an average of 33.8 sapwood rings.

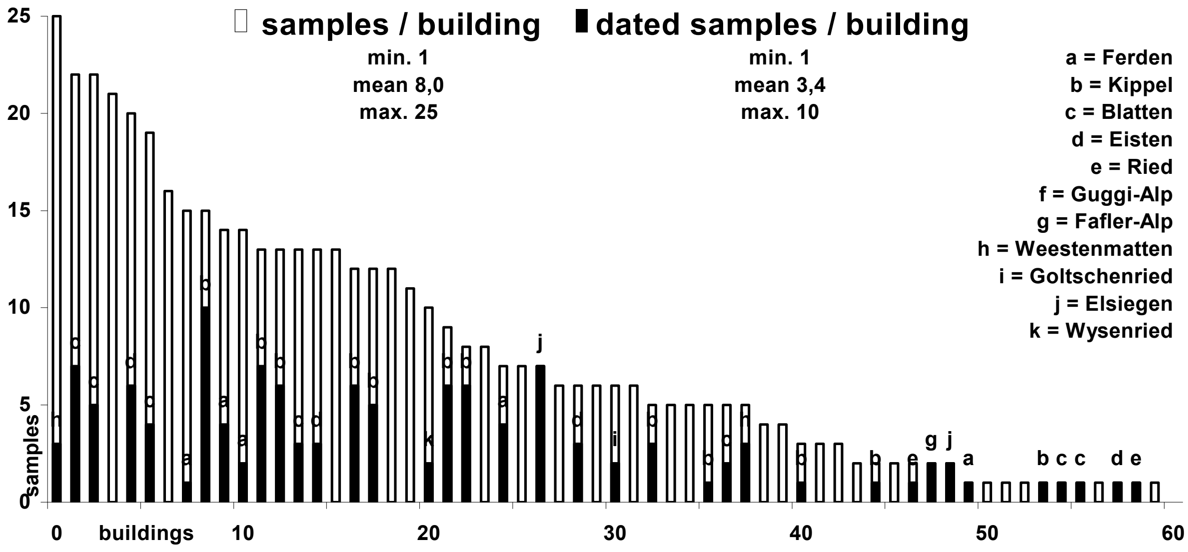

Figure 3: Numbers samples per house in the Lötschental, collected and dated within this study.

From the 152 dated historical samples, 21 contain the pith. Robust pith-offset estimates could be made on another 110 cores. From these, 80 cores miss the pith by 10 years or less. 30 samples have pith-offset estimates greater than 10 years. For the remaining 21 cores pith-offset estimates were not possible, because of incomplete cores. Historical construction wood from the Lötschental, classified into 7 groups by the date of the outermost dated ring is summarized in figure 4. Each circle represents an individual sample. The observed pattern partly results from patchy sampling throughout the Valley and does not consider the presence of the waney edge. Therefore these patterns should not been over interpreted. In an attempt to date buildings properly the existence of the waney edge is necessary to date the felling. Similarly, the number of samples per building should in general range between 5 and 8 well chosen samples. The actual number of cores per building needed to ensure correct dating of buildings is individually related to the building size, the architecture, the historical metadata background and the identification as well as the number of different building phases. After precise dating, verification of the existence of the waney edge and consideration of building phases, houses can be dated by adding one year to the felling date.

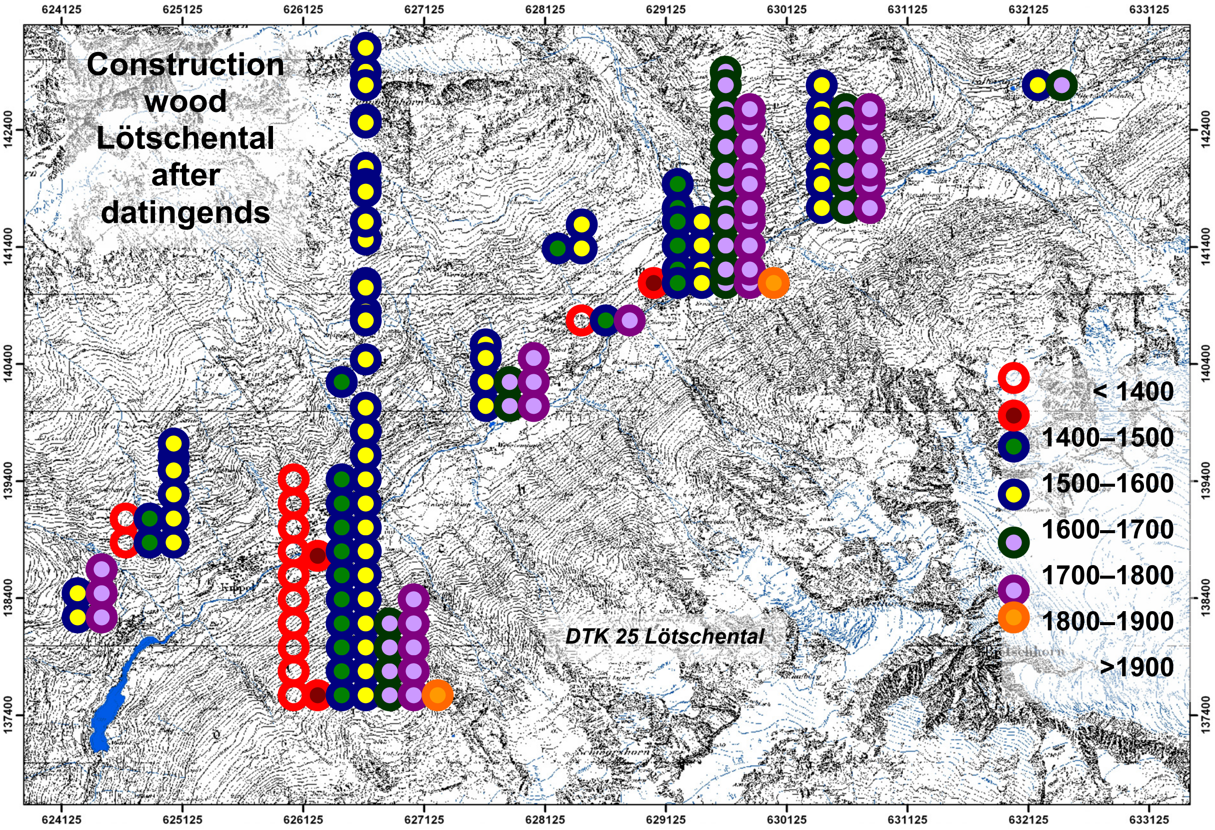

Figure 4: Spatial distribution of the Lötschental series computed after end-dates

This value is based on the fact that construction wood was processed shortly after felling (Hollstein 1980). The so-called “green-wood” allows for easier handling of the beams (Schmidt et al. 2001). The successful dating of samples that do not include the waney edge, is a function of the number of cores within the same building including the waney edge, as well as the existence of sapwood, which allows an estimation of the felling date by 20 ±5 years. Furthermore, historical details, such as inscriptions and ornaments, provide useful dating information.

Conclusions

In order to develop a 1300-year long chronology for the Lötschental area, samples from living trees and historic buildings were combined. Here, we demonstrated the possibility of crossdating such samples from larch trees and pointed to the potential of using this 1300-year record for climate analyses. This conclusion is confirmed by the substantial common variance that occurs in the period of overlap between samples from living and relict material. Similarities are seen in the inter-annual to multi-decadal frequency domains. To reach this feature, the data were detrended by fitting 300-year fixed splines. The common variance on the inter-decadal time scales in both the living and relict samples are likely related to summer temperature variations.

As another outcome of these efforts, a significant number of old buildings were dated in the Lötschental. These data are useful to further complete the understanding of settlement history in this Central Alpine valley. We intend to provide a more detailed description of this history together with historians from the Valais. An interdisciplinary approach is necessary to reach this goal.

The current study also demonstrates that individual detrending methods utilizing 300-year splines would not be useful to address longer-term changes of temperature variation. To study the potential of analyzing centennial climatic trends, we intend to apply age-related standardization methods, such as the Regional Curve Standardization (RCS) (Esper et al. 2002) or the Age – Banding technique (Briffa et al. 2001), to these data. On theoretical grounds, the size of the dataset now compiled is large enough to use such standardization techniques.

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