Tree-ring based chronology of debris-flow events and deposition processes at Ritigraben (Valais, Swiss Alps) since AD 1570

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Growth disturbances in century-old trees were used to assess debris-flow activity on the forested cone of the Ritigraben torrent (Valais Swiss Alps), providing an unusually complete record of past events and deposition of material. The study of 2246 tree-ring sequences sampled from 1102 European larch (*Larix decidua* Mill.), Norway spruce (*Picea abies* (L.) Karst.) and Swiss stone pine (*Pinus cembra* ssp. sibirica) trees allowed reconstruction of 123 events since A.D. 1570 (Stoffel and Beniston, 2006; see Fig. 1). Tree-ring records suggest that comparably cool summers with frequent snowfalls at higher elevations regularly prevented the release of debris flows between the 1570s and 1860s and that the warming trend in conjunction with greater precipitation totals in summers and falls between 1864 and 1895 led to an increase of meteorological conditions favorable for the release of events from the starting zone. Enhanced debris-flow activity continued well into the 20th century and reconstructions show a clustering of events for the period 1916–1935, when warm-wet conditions prevailed during summers in the Swiss Alps. Very low activity can, in contrast, be observed for the last 10-yr segment (1996–2005) with only one debris-flow event recorded on August 27, 2002 (Stoffel et al., 2005). The reconstructed frequency is also in agreement with chronicle data on flooding events in Alpine rivers of Switzerland (Pfister, 1999), where a scarcity of flooding events can be observed for most of the LIA and during the mid-20th century as well. However, it is worthy to note that floods in adjacent Alpine rivers started to become more frequent in the 1830s, which is three decades before activity increased in the investigated case-study area.

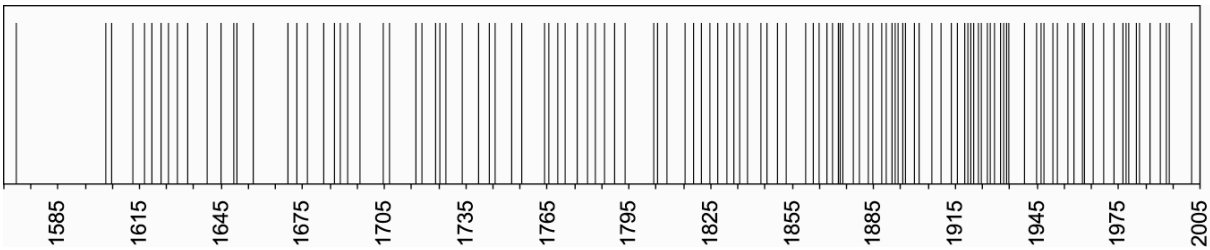

Figure 1: Tree-ring based reconstruction of debris flow activity at Ritigraben between AD 1566 and 2005 containing 123 events.

The seasonality of past events (Fig. was assessed based on the intra-annual position of tangential rows of traumatic resin ducts in the tree rings, archival data on flooding in rivers of the Valais Alps as well as on meteorological records of the local MeteoSwiss station (1863–2005). Results on the seasonality of debris-flow activity are presented in Fig. 2 and indicate that events generally occurred much earlier in the summer prior to 1900. This is especially true for the period 1850–1899, when more than 70% of the reconstructed debris-flow events took place in June and July

and no incidence in September. In the 20th century, debris-flow activity clearly shifted towards August and September, with not a single event registered for June after AD 1962. We also observe that over the past decades, events occurred more frequently in the form of cyclonic rainstorms in autumn rather than as convectional rainfalls in summer.

Based on the result of geomorphic mapping, we are also able to date 86% of the lobes identified on the present-day surface of the intermediate cone. A majority of dated material was deposited over the last century, and results clearly show that signs of pre-20th century events are usually recognizable in the tree-ring record of survivor trees, but the material that caused the growth anomaly in trees would have been completely overprinted or eroded by more recent debris-flow activity. The overprinting of deposits by subsequent events is supposed to be important at Ritigraben, as the volume of deposits identified on the present-day surface only accounts to 78,600 m^3 as compared to the total volume of the cone estimated 4.3×10^6 m^3 (Stoffel, 2006). But we also believe that there must have been periods with more abundant debris entrainment from the starting zone and in the main channel in the Holocene than during the last few centuries. Based on the geomorphic map and the dendrogeomorphological dating of events, we conclude that debris-flow activity of the 20th century was characterized by sediment accumulation on the cone and that the high-magnitude event in September 1993 (60,000 m^3) has most probably to be seen as the only major incision events on the cone for at least the last century. We are thus aware that overprinting and (partial) erosion of older deposits are important processes in the present-day accumulation of deposits on the cone and that a realistic image of spatial activity can only be provided for the 20th century at best.

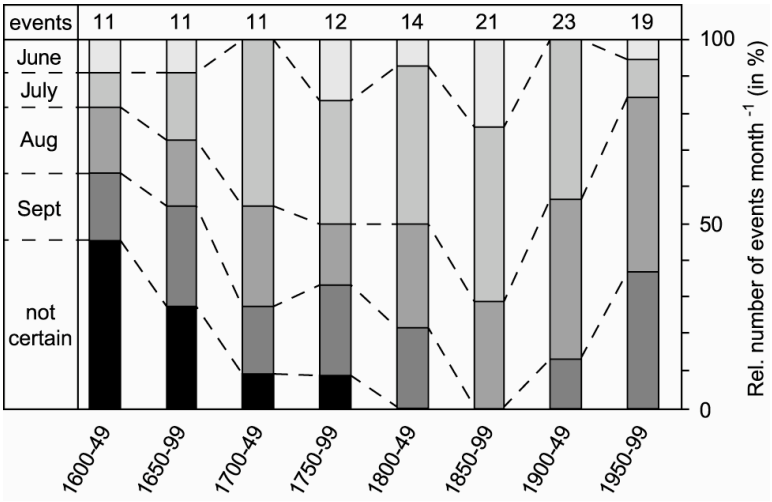

Figure 2: Seasonality (JJAS) of past debris-flow activity as inferred from the intra-annual position of rows of traumatic resin ducts in the tree ring as well as on archival and MeteoSwiss data.

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