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Research paper

Testing dendrogeomorphic approaches and thresholds to reconstruct snow avalanche activity in the Făgăraş Mountains (Romanian Carpathians)

Patrick Chiroiu [a, *], Markus Stoffel [b, c], Alexandru Onaca [a], Petru Urdea [a]

[a] Department of Geography, West University of Timişoara, Str. V. Pârvan nr.4, 300223 Timişoara, Romania
[b] Dendrolab.ch, Institute of Geological Sciences, University of Berne, Baltzerstrasse 1+3, CH-3012 Berne, Switzerland
[c] Institute for Environmental Sciences, University of Geneva, 7 route de Drize, CH-1227 Carouge-Geneva, Switzerland

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ABSTRACT

Snow avalanches are a widespread natural phenomenon in steep mountain environments, where they modulate landscapes and frequently disturb forest stands. Such disturbances in trees have been used since the 1970s to retrospectively date avalanches, study their extent and reach, as well as to document their triggers. Although virtually every dendrogeomorphic paper is still based on the concepts established by Shroder (1978), important methodological improvements have been achieved in the field ever since and more particularly over the last decade. This study therefore reports on recent methodological progress and employs three different approaches (i.e. *Shroder* index value and *Kogelnig-Mayer* weighted index value) and different sets of signals in trees (i.e. inclusion of tangential rows of traumatic resin ducts as evidence of past avalanching) to record snow avalanche activity. Using 238 increment cores from 105 *Picea abies* (L.) Karst trees which colonize a snow avalanche path in the Romanian Carpathians, we illustrate possibilities and limitations of the different approaches for the period covered by the chronologies (1852–2013). In addition, we sampled 30 undisturbed *P. abies* trees from a forest stand north of the avalanche path, where no geomorphic disturbance was identified, so as to build a reference tree-ring chronology. The three avalanche chronologies constructed with the disturbed trees allow identification of past process activity, but results differ quite considerably in terms of avalanche frequency, number of reconstructed events and their temporal distribution. Depending on the approach used, 15 to 20 snow avalanches can be reconstructed, with the best results being obtained in the dataset including tangential rows of traumatic resin ducts. The addition of this anatomical feature, formed after mechanical impact enlarges the number of growth disturbances by 43.5%, and can thus explain the increase of reconstructed avalanches by one-third as compared to the results of the chronology using the “conventional” *Shroder* approach.

1. Introduction

Snow avalanches are among the most frequent slope processes in mountain environments (Luckman, 1977; Eckerstorfer et al., 2013). When occurring in populated areas, they represent a major threat to human lives and property, calling for hazard mitigation and risk management measures, including their artificial release (Weir, 2002). By contrast, in isolated regions, avalanches are exclusively driven by natural triggers and develop typical spatio-temporal patterns, thereby offering ideal conditions to study the process under natural conditions.

In forested avalanche paths, trees have been demonstrated to be precise recorders of past geomorphic activity, thus the occurrence and characteristics of past events can be deciphered using dendrogeomorphology (Alestalo, 1971; Shroder, 1978). Dendrogeomorphic techniques are based on the fact that trees will provide evidence of past disturbance in their growth ring record (process-event-response; Shroder, 1978). Tree-ring studies have been applied widely for the reconstruction of avalanche chronologies (Casteller et al., 2011; Corona et al., 2012a), to assess their frequency (Reardon et al., 2008) and magnitude (Butler and

* Corresponding author.
E-mail address: p.chiroiu@gmail.com (P. Chiroiu).

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Malanson, 1985; Dubé et al., 2004; Schläppy et al., 2014), as well as the spatial extent of past events (Stoffel et al., 2006; Corona et al., 2010). At the same time, tree-ring based reconstructions of snow avalanches have also served the study of relationships between snow avalanches and climate variables (Germain et al., 2009; Muntan et al., 2009; Schläppy et al., in press). Although virtually every dendrogeomorphic paper is still based on the seminal papers and techniques established by Shroder (1978, 1980), important methodological improvements have been achieved in the field ever since and more particularly over the last decade (Reardon et al., 2008; Germain et al., 2009; Kogelnig-Mayer et al., 2011; Corona et al., 2012b; Schläppy et al., 2013). Recently, the lack of agreement among researchers upon minimum sample size and minimum responding trees (discussed by Butler and Sawyer, 2008), as well as the assessment of different response intensity classes (Germain et al., 2009; Casteller et al., 2011; Kogelnig-Mayer et al., 2011), have urged the need for setting clear guidelines and standards in dendrogeomorphic applications. In this respect, the questions of optimal sample depths, minimum numbers of responding trees and index value thresholds have been tested statistically and new standards have been suggested (Corona et al., 2012b, 2014; Stoffel et al., 2013). Likewise, Kogelnig-Mayer et al. (2011) have developed a response intensity weighted index, whereas Stoffel and Corona (2014) have proposed a standard method for all geomorphic processes to classify growth reactions in trees according to their intensity. Improvements have also been made regarding the identification of new growth disturbances in tree-rings (in addition to those widely utilized since the 1970s, such as injuries, reaction wood, abrupt growth changes). This is the case for tangential rows of traumatic resin ducts (Stoffel, 2008), which provide accurate information on the timing of events and offer the possibility of differentiating between several geomorphic processes occurring at the same study site (Stoffel et al., 2006; Stoffel and Hitz, 2008; Szymczak et al., 2010).

Despite the continuous improvements made in dendrogeomorphic techniques, the Shroder approach (referred hereafter as ‘conventional approach’) still represents the backbone of every tree-ring study (Butler and Stoffel, 2013). The latest standards developed in the field, however, aim at increasing the confidence of dendrogeomorphic results and at optimizing cost and benefit in fieldwork and laboratory analyses. One might thus ask the question what the differences are between results of ‘modern’ as compared to ‘conventional’ approaches.

The present study, undertaken on an avalanche path located in a remote area of the Romanian Carpathians, wants to address these research questions by comparing the results of the ‘conventional’ approach towards the outcomes obtained by using the latest developments in the field of dendrogeomorphology. At the same time, a secondary and implicit objective of this paper is the reconstruction of spatio-temporal patterns of snow avalanches that occur on the investigated path.

2. Study site

The avalanche path (45°36′59″N, 24°36′25″E) investigated here is located on an east-facing slope in the Arpaş Valley, Făgăraş Mountains (Southern Carpathians). The Făgăraş Mountains are the highest part of the Romanian Carpathians with 8 peaks over 2500 m asl and clear evidence of Quaternary glaciations and contemporary periglacial processes. The Arpaş Valley is a north-south oriented valley located in the central part of the Făgăraş Mountains (see Fig. 1 for details), and largely void of human activities. Specific landforms, deposits and vegetation features witness the recent activity of geomorphic slope processes such as snow avalanches, debris flows and rockfall. The geological setting consists of easily weathered foliated crystalline schists (phillites and micaschists), gneisses and amphibolitic schists, as well as limestone intrusions.

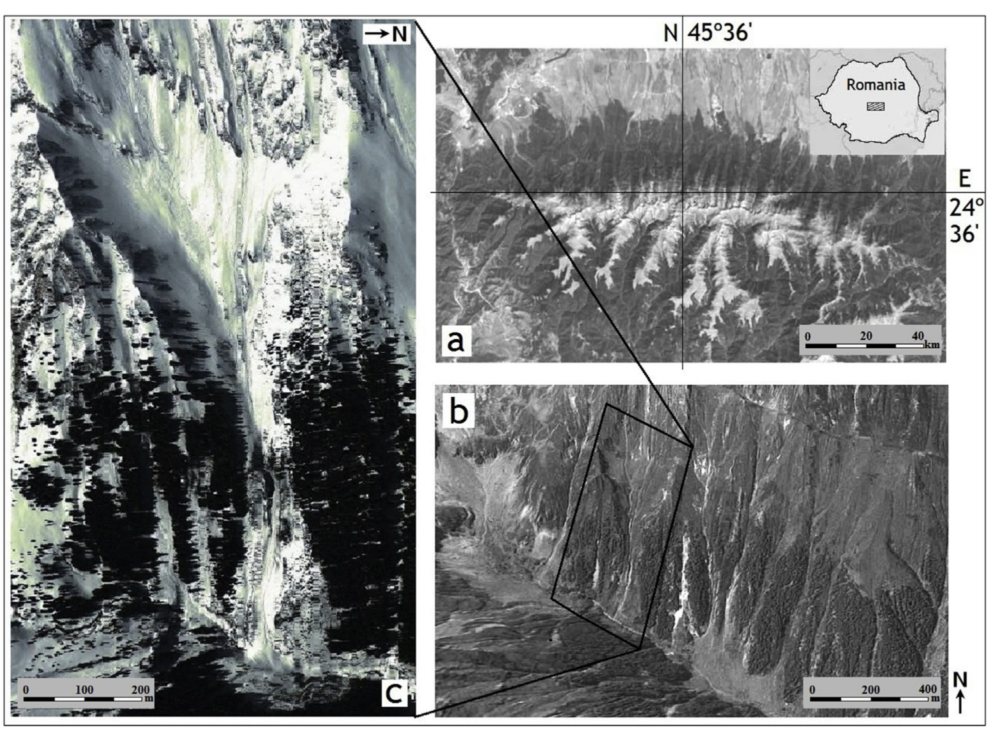

Fig. 1. Location of the study area: (a) Făgăraş Mountains (Southern Carpathians, Romania) (b) Arpaş Valley (c) MP Avalanche Path (source: Google Earth, 2012).