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# The Thurwieser rock avalanche (Italian Alps): Description and dynamic analysis

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ABSTRACT

A rock avalanche of about $3 \cdot 10^6$ m$^3$ detached from the South-East flank of the Punta Thurwieser ridge (Italian Central Alps) on the 18th of September, 2004.
Due to the characteristics of the moving material (i.e. rock, debris, ice, snow) and the path of propagation (e.g. presence of a glacier), the mass was able to rapidly cover long distances (about 3000 m).
Among the possible causes of the event, attention is mainly focused on permafrost degradation and changes in glacier extension due to global warming.
In the present work, the dynamics of the event and the role played by characteristics of the propagation path are numerically investigated with the RASH3D code, based on a continuum mechanics approach.
Results obtained with two rheological hypotheses (Frictional and Voellmy) are compared and discussed. In particular, it emerges that 1) the use of a Voellmy rheology with a reduced friction angle on the glacier is necessary to reproduce the dynamics of the Thurwieser event, and 2) a lack in knowledge of geometrical and geomechanical information may lead to wrong interpretations of the event and inaccurate calibration of numerical models.



## 1. Introduction

Rock avalanches pose a serious threat throughout the mountain regions all around the world. The high velocity that mass can reach during propagation, due to the characteristics of both the moving material (i.e. rock, debris, ice, snow) and the type of superficial layer of the propagation path (i.e. vegetation vs. glacier), permits that long distances are rapidly covered.

Furthermore, rock avalanches impact is becoming more and more pronounced due to increasing mountain tourism in both summer and winter time and to global warming that, causing permafrost degradation and changes in glacier extension, is nowadays heavily contributing in increasing rock slope instability and by consequence landslide hazard.

It follows that a suitable risk assessment is needed to prevent lost of human lives and damage to infrastructures. As to this, the prediction of rock avalanche runout area is fundamental.

Many powerful numerical methods now exist (e.g. Chen and Lee, 2000; Denlinger and Iverson, 2004; McDougall and Hungr, 2004) to investigate the dynamics of rock avalanches. In this frame a promising approach for describing flows on complex geometries is represented by methods that are based on continuum mechanics (i.e. the heterogeneous real mass is treated as a continuum) and assume that the avalanche thickness is very much smaller than its extent parallel to the bed. These hypotheses allow the use of depth averaged Saint Venant equations, in which a complete three dimensional description of the flow is avoided (Savage and Hutter, 1989).

Whatever code is used, the problem of the choice of the correct rheology and of the rheological parameter values arises. Due to the large dimensions of real phenomena, back analyses of rock avalanches that already occurred are the only way to obtain data for runout prediction analyses (e.g. Hungr and Evans, 1996; Pirulli, 2005). Nevertheless, a lack of knowledge in geometrical and geomechanical information may lead, in the back analyses, to wrong interpretations of the mechanics of the event and inaccurate calibration of numerical models.

Main uncertainties in geometrical and geomechanical data usually concern: 1) the estimation of the volume; 2) the reconstruction of the pre-event topography; 3) the identification of the slope sectors with different characteristics; 4) the definition of the constitutive laws; 5) the distinction between erosion and deposition areas; and 6) the water pressure distribution.

The recent Thurwieser rock avalanche (Italian Central Alps) has been selected in the present paper as case study in consideration to the high degree of complexity of its geometry, to the presence of a glacier along the runout path and to the unexpectedly long propagation distance of the mass. Moreover, a good knowledge of the site exists, both in terms of qualitative and quantitative data.

The RASH3D code (Pirulli, 2005), based on the continuum mechanics hypotheses and allowing for the choice among various rheological laws, is here applied to verify its capability of reproducing the propagation of a complex event and to investigate the influence of geometrical and rheological parameters on the dynamics and mechanics of the Thurwieser rock avalanche.

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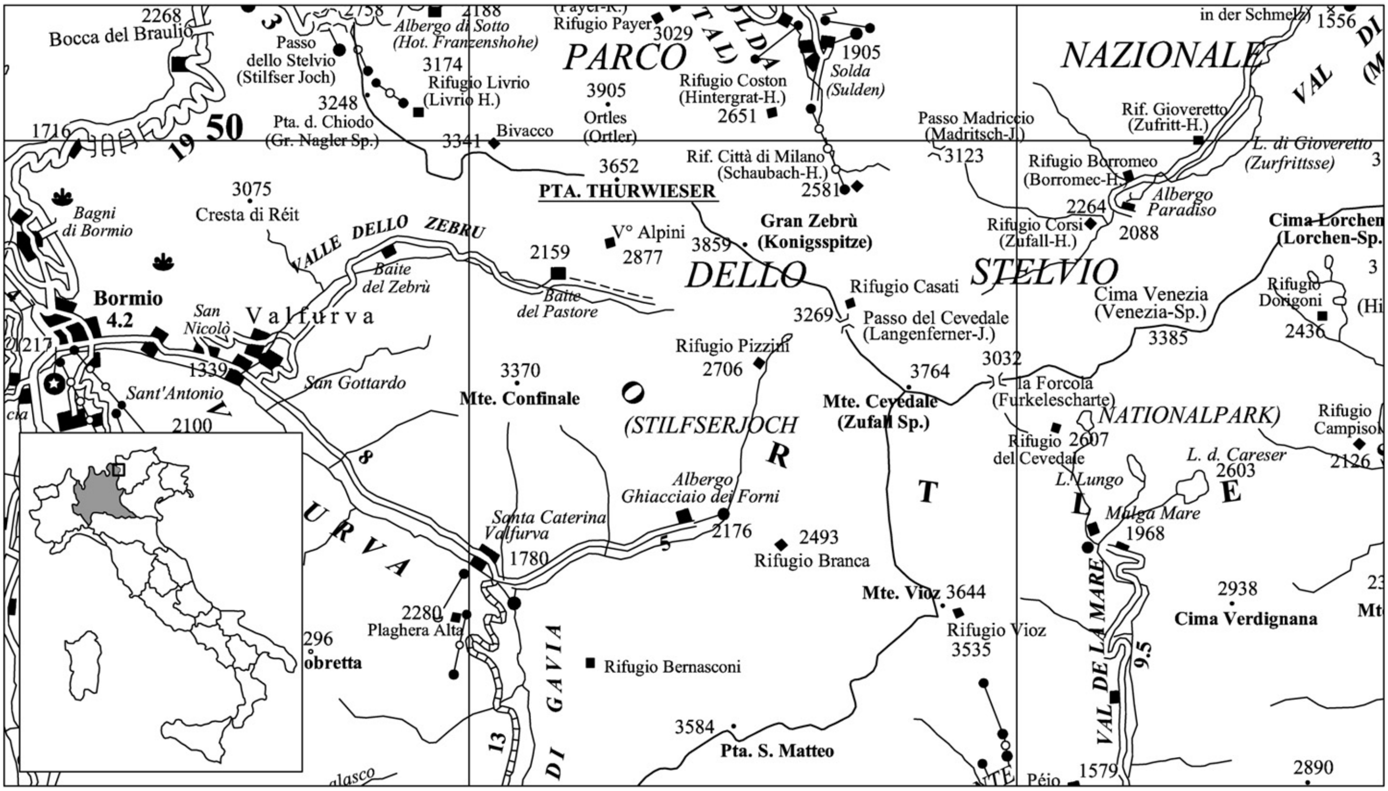


**Fig. 1.** Location of the study area.

The paper consists of three main parts. The first part focuses on the characterization of the Thurwieser study area. The second part briefly describes the continuum mechanics modelling hypotheses and gives details of the applied numerical code RASH3D. In the third part, results of the back analysis of the propagation of the Thurwieser rock avalanche are presented. The obtained results are then compared and discussed.

## 2. The Thurwieser rock avalanche

The Thurwieser rock avalanche, involving a volume of about $3 \cdot 10^6$ m$^3$, detached on the 18th of September, 2004 from the South-East flank of the Punta Thurwieser (3657 masl), in the Italian Central Alps (Figs. 1 and 2).

Based on performed surveys and gathered witnesses, many authors tried to give a reconstruction of the Thurwieser collapse and dynamics (e.g. Dei Cas et al., 2004; Cola, 2005).

### 2.1. Triggering causes

Since the area of Bormio (Sondrio, Italy) (Fig. 1) is characterized by an important seismic activity, the possible influence of this aspect was initially investigated. The analysis of the Campo dei Fiori (Varese, Italy) digital seismograph records (about 150 km far from the event site) underlines the presence of only a background noise in coincidence of the rock avalanche event. Therefore, the recorded background noise cannot be assumed as the cause of the event but, more realistically, as the consequence (Dei Cas, 2004).

Attention was then focused on the analysis of climatic conditions. Two weather stations located near the event area, at an elevation of 2140 masl and 1250 masl respectively, indicate that heavy rains had no place during the event previous week. Temperatures recorded on the 15th and 16th of September let suppose upper-level snowfall; while, the wide temperature range of the 17th and, above all, the increase of about 14° recorded between the morning and the afternoon of the 18th probably contributed in melting the existing blanket of snow. Anyway,

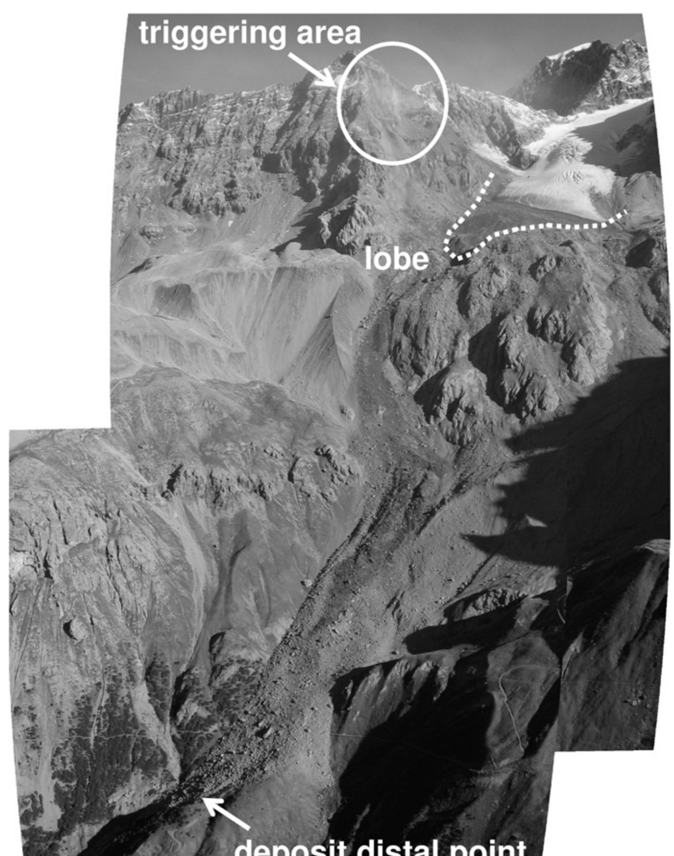


**Fig. 2.** The Thurwieser rock avalanche. Image courtesy of Regione Lombardia (Italy).