Experiences in avalanche assessment with the powder snow avalanche model SamosAT

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ABSTRACT: In 2004 the Forest Technical Service for Avalanche and Torrent Control (WLV) has initiated the development of the new powder snow avalanche model SamosAT. The program SamosAT provides simulation tools for dense and powder snow avalanches. The previous Samos simulation platform has been reworked in order to obtain improved simulation results, new calculation methods and enhanced software handling. Major changes have been made in the dense flow friction model, in the alteration of the simulation environment of the powder part with enhancements in the 3D suspension mesh and finally in optimising the resuspension layer, which is responsible for the transition of the dense snow into the powder layer. The calibration of the model was done with 22 well documented reference avalanches. The model was released in the end of 2007 and officially implemented in the daily work of avalanche danger assessment and hazard mapping. In the last years numerous simulations have been done with the model including recalculations of actual avalanche events from 2009. This paper gives information about the experiences with the avalanche model SamosAT. On the basis of several case studies the improvements as well as the limits of the new program are explained.

KEYWORDS: avalanche simulation, SamosAT, model calibration, avalanche case studies

1 INTRODUCTION

The Forest Technical Service for Avalanche and Torrent Control has applied different avalanche models for practical use for many years. In the beginning of 1999 the first 3D avalanche simulation model called Samos (Snow Avalanche Modelling and Simulation) was released by the authorities (BMLFUW) in cooperation with the company AVL List GmbH in Graz. The program enabled both, a dense and a powder snow avalanche simulation in 2D and 3D.

New technologies, developments in snow sciences and the demand for a more detailed and comprehensible hazard mapping led to a further step in the development of the 3D powder snow avalanche model Samos. As a result, a new model – SamosAT – was initiated in 2004 and released in October 2007. The advanced model provides simulation tools for dense and for powder flow avalanches, depending on the respective settings. The previous Samos simulation platform has been totally altered in order to provide improved results and an easier software handling. In regard of these enhanced technologies the appellation Samos has been adapted by the affix AT for the Advanced Technology.

2 OBJECTIVES

The Samos model (release 1999) significantly overestimated the total avalanche runout distances. Especially the simulation of the dense flow part resulted in non satisfying outcomes mainly due to the friction model. The powder model, which is coupled with the dense flow part, overrated the runout particularly in the pressure zone between 1–5 kPa. Therefore, the main emphasis in the development of SamosAT was the proper modelling of the dense flow part and the improvement of the runout behaviour for the powder part.

3 METHODS

Major changes have been made in the calculation of the dense flow part, in the alteration of the simulation environment of the powder part and finally in optimising the resuspension layer, which is responsible for the transition of the dense snow into the powder layer.

Extensive tests with various friction laws were necessary to find a suitable setup for properly modelling the dense flow avalanche.

\[
t_{\text{d}}(\theta) = t_0 + \tan\delta \left(1 + \frac{R_s}{R_s^0 + R_s}\right) \cdot \sigma_{\text{d}}(\theta) + \frac{\rho u^2}{\left(1 - \ln \frac{\bar{R}}{R} + B\right)^2}
\]

[1]
The SamosAT friction law \[1\] in the actual setting provides suitable runout behaviour. The bed friction angle \(\tan \delta\) still plays the decisive role in the calculation of the maximum avalanche runout. The term \((R_s^0, R_s)\) increases the bed friction angle at lower avalanche velocities in order to stop smaller avalanches more realistically and to prevent lateral spreading of avalanches at very low flow heights (under 0.5 m depending on the setting). \(R_s^0\) is an empirically determined constant to reduce the spreading of avalanches at very low velocities.

Another step was the alteration of the irregular Delauny triangulation to a constant Eulerian grid. This improves the calculation time, increases the stability and reduces random outliers.

The flexible user interface provides extended possibilities in avalanche simulations especially in the data input and output.

Figure 1. Overview of the avalanche modelling SamosAT (AVL)

The calculation of the powder snow avalanche in the newly released model is performed on an AVL-Swift V8 platform. The basic formulas have been adapted to the SamosAT model. Additionally, a real two phase calculation model of ice particles and air has been integrated to obtain a more realistic simulation of the aerosol. Besides the gain of mass particles, this method allows for a supplementary loss of snow particles along the avalanche path. Consequently, snow particles can rise and drop within the aerosol especially at strong surface bends.

In the meantime there are two different possibilities to generate the 3D-calculation mesh (Fig. 2) for the aerosol. The usual method was a rectangular mesh of 20x10x4m (lxwxh). But this was often not stable enough especially in rough avalanche terrain. Therefore the AVL developed a new way to generate a quadratic calculation mesh with a resolution of 15x15x4m.

Figure 2. Calculation mesh powder part

4 AVALANCHE MODELLING – CASE STUDIES

With recalculation of avalanche events and analysis of case studies the quality of the simulation results can be verified.

4.1 Case study “Fleisskargraben” avalanche

In February 2005 and 2009 the Fleisskargraben avalanche (Sölktal/ Styria) reached the valley bottom. The avalanches started at 2075m with a total fall height of 1150m and caused some minor damages at the settlement at around 920m.

Figure 3. Recalculation of the powder snow avalanche event Fleisskargraben in Feb. 2005 (dotted line marks the mapped avalanche runout, the lines visualize the simulation)
The release area comprises 23.9 ha. The avalanche in 2005 was a powder snow avalanche and in 2009 it was rather a dense flow avalanche. The avalanche was documented and mapped by Mayerl et al. (2005) as well as (2009).

The avalanche powder part hit the valley bottom in 2005, ran up the counter slope, turned in the opposite direction and caused some minor damages on the entrance of the house. A recalculation of this avalanche showed good fitting with the mapping. Especially the calculated 5kPa pressure line also showed this effect (Fig. 3).

Another avalanche occurred on the 27th of February 2009 in the same area. This time the dense flow process dominated. The figure 4 shows this recalculation of the event in 2009.

4.2 Case study “Gallreide” avalanche

In the Gschnitz valley occurred a big powder snow avalanche on the 25th of February 2009. This Gallreide avalanche event reached the street in the valley bottom and enormous amounts of snow up to 4m were settled by the avalanche besides the farm house “Bodeler”, which is more than 300 years old. Luckily no damages on the farm house were detected observed. This is a well known avalanche path, but the lateral spreading of this event in the direction of the farm house was unusual. The turn to the orographic right side of the dense flow part of the mixed avalanche was induced by the deposition of previous avalanches during the night before. The powder part passed the farm house without any damages in the usual path (Fig. 5). By chance an observer could take a picture of the avalanche aerosol.

The avalanche release occurred at 2300m asl. in rocky terrain, the deposition was at 1250m in the valley bottom, which means a total fall height of 1050m.

On the 26th of February the avalanche was studied and surveyed. Snow deposition heights were measured with probes and marked with GPS points to locate the results. The figure 6 displays the avalanche mapping with the GPS points as well as the simulation results of the powder part. Further details of the avalanche forces and the maximum runout were obtained by studying signs in the field i.e. the snow loads on the trees besides the path or the pile of wood on the orographic right side of the runout, which were unspoiled.
The data from the Gallreide avalanche allowed a good study of the most important simulation parameters. Especially for the calculation of the powder part it is necessary to optimise the parameter setup, which gives the best fitting for the reference avalanches. By using a matrix (Fig. 7) the best set up of the avalanche parameters i.e. particles restitution coefficient, particles suspension coefficient and the turbulent exaggeration factor was found for this case. Studies like this allow an optimisation of the standard simulation parameters for the complex process of powder snow avalanches.

5 DISCUSSION AND RESULTS

Within the Forest Technical Service for Avalanche and Torrent Control avalanche simulations are in use for long time. The experiences with the simulation tool SamosAT are in general good, though it is crucial to know the limits of the model to obtain realistic simulation results. Smaller known avalanche events give the possibility to calibrate the model on site for the main calculation of the catastrophic avalanche.

For the model validation, 22 well documented avalanche events have been chosen to calibrate the various internal parameters. The reference avalanche data pool contains mapped avalanche runout zones, information on measured snow heights, approximated avalanche pressures at damaged buildings and/or recalculated avalanche velocities. This rather punctual information is, in addition to the surveyed avalanche outlines, taken into account in the calibration of the dense and powder flow models.

The comparison of simulations and reference data showed satisfying results for the recalculation of the dense part. The calculated lateral spreading in the runout zone can be minimised by increasing the bed friction angle at low avalanche velocities. Hence the SamosAT dense flow model reacts sensitively to the surface topography.

The simulations of the powder avalanche showed a significant decrease of the spreading in the runout zone in comparison to the reference data. The modelling with the proposed parameter setting for the powder part led to more realistic avalanche speed and pressure by SamosAT. The calculation of mass balances were in general in agreement with the release mass of the observed avalanche events and the runout behaviour.

The recalculations with 22 reference avalanche events pointed out the applicability of the SamosAT model for operational use. The model simulates dense flow avalanches as well as powder snow avalanches in general in a suitable way.

The practical use of SamosAT in the daily work for hazard zone mapping, dimensioning of avalanche protection measurements showed that simulations along strongly channelized avalanche paths can lead to underestimated maximum runouts. In contrast, the simulations of very wide and straight avalanche paths produce too much avalanche mass in the suspension layer, because of high velocities. The use of an alternative suspension calculation which is already implemented in SamosAT show better fitting in these cases. A revision of the new calculation setup with the reference avalanches is currently in progress to validate the parameters.

The recent avalanches from 2009 showed once more that wet snow avalanches cannot be simulated with the existing tools. This type of avalanche contains a certain factor of random runout behaviour, which cannot be properly simulated so far.

Also small avalanches with less than 20,000m³ often overestimate the maximum runout. It has to be taken into account that the model was developed and calibrated for the simulation of catastrophic avalanches.

6 RESUME

The application of a complex simulation tool by well trained users ensures comprehensible results of high quality. Expert knowledge and experiences in simulations are necessary to distinguish between feasible and unusable simulations. Case studies assist in optimising the tool and in developing new methods to steadily improve the simulation model.

7 REFERENCES


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\begin{array}{|c|c|c|c|c|c|c|c|c|}
\hline
 & C_{\text{AB}} & C_{\text{AB}} & C_{\text{AB}} & \text{Legende} \\
\hline
\text{FLÄCHE} & 1.5 & - & + & + & 0.045 & 0.955 & 0.065 & 0.965 & 0.956 & 0.965 \\
(\text{3 kPa}) & 1.3 & - & - & 0 & 0 & + & 0 & 0 & 0 & 0 \\
1.0 & - & 0 & 0 & + & + & 0 & 0 & 0 & 0 \\
0.01 & 0.02 & 0.03 & 0.04 & 0.05 & 0.06 & 0.07 & 0.08 & 0.09 & 0.10 \\
\hline
\text{LÄNGE} & 1.5 & - & + & + & 0.045 & 0.955 & 0.065 & 0.965 & 0.956 & 0.965 \\
(\text{3 kPa}) & 1.3 & - & - & 0 & 0 & + & 0 & 0 & 0 & 0 \\
1.0 & - & 0 & 0 & + & + & 0 & 0 & 0 & 0 \\
0.01 & 0.02 & 0.03 & 0.04 & 0.05 & 0.06 & 0.07 & 0.08 & 0.09 & 0.10 \\
\hline
\text{FORM} & 1.5 & 0 & 0 & + & 0.045 & 0.955 & 0.065 & 0.965 & 0.956 & 0.965 \\
(\text{2 kPa}) & 1.3 & - & - & 0 & 0 & + & 0 & 0 & 0 & 0 \\
1.0 & - & 0 & 0 & + & + & 0 & 0 & 0 & 0 \\
0.01 & 0.02 & 0.03 & 0.04 & 0.05 & 0.06 & 0.07 & 0.08 & 0.09 & 0.10 \\
\hline
\text{GESAMT} & 1.5 & 0 & 0 & + & 0.045 & 0.955 & 0.065 & 0.965 & 0.956 & 0.965 \\
 & 1.3 & - & - & 0 & 0 & + & 0 & 0 & 0 & 0 \\
 & 1.0 & - & 0 & 0 & + & + & 0 & 0 & 0 & 0 \\
 & 0.01 & 0.02 & 0.03 & 0.04 & 0.05 & 0.06 & 0.07 & 0.08 & 0.09 & 0.10 \\
\hline
\end{array}
\]

Tabelle 1: Übersicht über die verschiedenen Parameterstellungen von \( c_p \), \( c_{\text{AB}} \) und \( c_{\text{C}} \) und deren Übereinstimmung mit der Idealeigenschaft (dunkel unterlegte Zeile).

Figure 7. Example of the matrix to evaluate the parameter setup for the recalculation of the “Gallreide” avalanche (the boxes mark the best fit)