EVALUATING APPROACHES TO ASSESS AVALANCHE HAZARDS FROM THE USER POINT OF VIEW

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ABSTRACT: Avalanche simulations are a common tool for hazard assessments with a variety of approaches to choose from the user point of view. Each of them is characterized by uncertainties, weaknesses and strengths, which arise with the determination of input parameters and material parameters. Regarding these issues, questions arise on the assets and drawbacks, on potential improvements and how avalanche tools are used in practice. To shed light on these questions, a survey among avalanche experts (e.g. researchers, practitioners, engineers) from various countries has been conducted. One of the key findings from that survey was associated with the approval of reliability of simulation results. It could be shown that the reliability attributed to the simulation results does not primarily depend on the certainty of the model assumptions and input parameters but rather on the expertise of the user and the availability of additional information (e.g. Chronicles, documentation of events, field observations). Another interesting insight could be found when it comes to the application of simulation results to a hazard assessment. It seems that simulation results play a secondary role and the expert's recommendations are more oriented on national regulation guidelines. Based on these findings a subsequent survey was set up. The focus of that second survey shall be given on the types of different approaches used for a hazard assessment and how they are applied in practice.

KEYWORDS: Expert interview, hazard management, modeling, simulation, snow avalanche.

1. INTRODUCTION

Within the realm of hazard management avalanche modeling has become a state of the art technique to predict relevant avalanche characteristics (Granig, 2012). Traditionally, avalanche models were used to assess runout lengths of rare, extreme events and to prepare hazard maps. Therefore, empirical models based on topographic characteristics (e.g. Alpha-Beta model by Lied and Bakkehøi, 1980) or simple dynamical models (Perla et al., 1980; Salm et al., 1990) were employed. With the use of computational simulations it became possible to calculate flow characteristics such as flow heights and velocities in up to three dimensions implementing the underlying flow models in user friendly software tools. Examples of such simulation tools are AVAL-1D (Christen et al., 2002), RAMMS::Avalanche (Christen et al., 2010), SamosAT (Granig and Oberndorfer, 2008), or RAMMS::Extended (Bartelt et al., 2016). Hence, the field of applications for such simulations tools has widened including the delineation of hazard zones (Arnalds et al., 2004; Sauermoser, 2006), vulnerability and risk assessments (Barbolini et al., 2004; Cappabianca et al., 2008) as well as for the planning and d design of permanent and temporal protection measurements (Sailer and Schaffhauser, 2008).

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With the extension of needs for safety regulations, the demands on model accuracy has risen, leading to the introduction of approaches of higher physical refinement.

The construction of such a simulation tool takes a physical theory as starting point which is transferred into a model of that theory that applies the theory to the physical process under consideration. Since there is no known material model that describes the variable flowing regime of an avalanche from a dense flowing avalanche of only a several meters height up to the formation of powder clouds of a few hundred meters of height, analogies from other fluid dynamical laws are drawn and different physical principles are incorporated that seem to describe the observed behavior in a plausible way. The stated model equations have to be numerically solved and implemented into a computer tractable algorithm, which is ultimately implemented in a software package. For each of these steps different methods can be chosen.

The application and the significance of such tools varies depending on the task, the country, and the availability. Moreover there exist more or less large uncertainties of input values (e.g. release area size, release height), internal model parameters (e.g. friction coefficients) along with implementation differences into computer algorithms (e.g. numerical scheme). Avalanche simulations are a powerful tool for hazard assessment. However, their application involves several assumptions and simplifications. Users struggle with the question how plausible and reliable the results are. As outlined by Winsberg (2001), the final result of a simulation tool consists of several inferential steps from its underlying theory to application.

Hence, the user's point of view plays an important role when evaluating such simulation results. A survey among avalanche experts has been conducted within the bDFA (beyond Dense Flow Avalanches) research project to give some insight into particular users decisions. This project was funded by the Austrian Academy of Science in the frame of Earth System Science Program. The questionnaire was conceived to shed light on the way how simulation tools are applied in practice, how the users judge their uncertainty and usefulness and how their influence on the hazard assessments is to be appraised. In this paper some salient results of that survey are presented and discussed. Moreover, insights gained by this study give rise to a consecutive survey that shall be conducted during the days of the International Snow Science Workshop 2018.

2. SELECTED RESULTS AND DISCUSSION

In total 51 representatives from 13 different nations participated at the questionnaire, with the predominant majority from Austria and Switzerland. 35% of the interviewees work in the private sector (engineering offices, civil engineers), 43% work on behalf of public-services and 22% are researchers from universities or from private research centers.

A total of 92% of the respondents indicated to use avalanche simulation results for their daily work. Most frequently used with 53%, 21% and 21% were the simulation tools RAMMS::Avalanche, SamosAT and Alpha-Beta, respectively. Other tools such as AVAL-1D, Voellmy-Salm, Elba+ or the PCM (Perla et al., 1980) were mentioned also, but seem to play minor role. Furthermore, different tools and models are often combined for hazard assessments, whereby country specific trends are evident. Most of the combinations that include SamosAT are used in Austria, often combined with Elba+, Alpha-Beta and sometimes with RAMMS::Avalanche. Most of the time RAMMS::Avalanche is used in Switzerland and here often combined with AVAL-1D, whereby RAMMS::Avalanche shows the largest international prevalence.

One of the central objectives of this investigation was the evaluation of simulation tools in general regarding the certainty of their input data (including their underlying assumptions and model parameters) and how these input data influence their result. The reliability of the simulation output had to be judged based on this information. In Figure 1 the major result of this inquiry is illustrated. A low certainty is attributed to the input data (red bars), which ranges from 50 to 60%. The only exception is the digital elevation model (DEM) to which a high certainty of slightly more than 80% is granted. All input data are regarded to have a high influence on the simulation output (green bars). Considering this results, one would expect a low reliability of the output data since they are based on mostly uncertain input values that have a high influence on them. Interestingly, an antithetic trend is visible. The simulation results are considered as quite reliable (blue bars).

The high reliability is supported by a very high agreement of the simulation results with chronicles rated with 74%. Also, the usefulness is considered to be very high with 77% (0=not useful at all, 100 very useful). Here, a discrepancy becomes evident that cannot be explained by solely looking at the model, its input data and how it is built and implemented in a software package. Rather the user of the model is the one who is aware of the shortcomings and nonetheless is confident to generate a reliable simulation results. In order to find an explanation of this discrepancy a look at the whole simulation process is inevitable. The use of simulation tools is only one brick in the methodical wall of the hazard assessment. An expert, who is assessing a hazard, will assemble every available information about that hazard and merges them to yield an overall picture as coherent as possible. The user takes the simulation result as one piece of the puzzle that has to agree with all the other pieces. Hence, the user may keep the results if they are suitable, reject them if not, or may perform further simulations with modified input data or parameters until the results seem to be suitable.

The respondents were asked to give a qualitative explanation for the given value of usefulness as well as a description of the workflow employed to

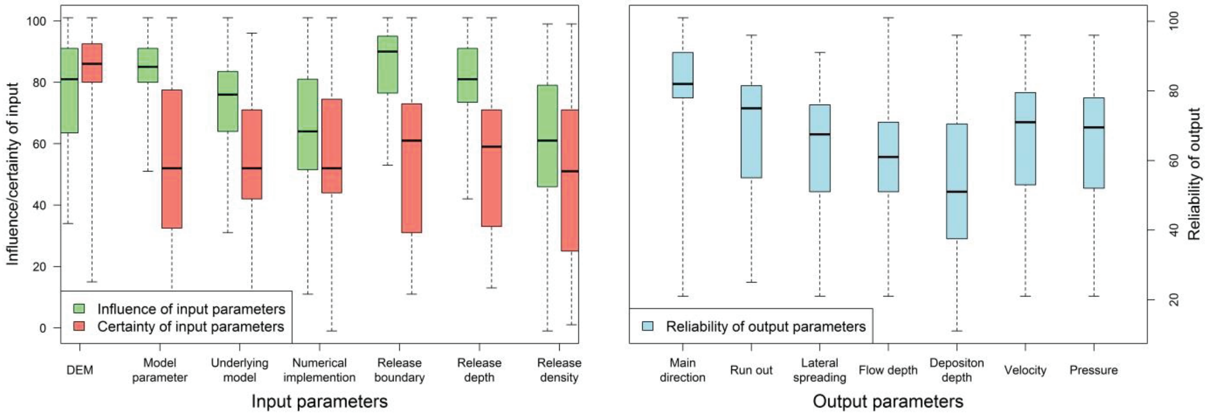

Figure 1: Evaluation of avalanche simulation input and output. The input parameters are rated with respect to their influence on the model result (0=no influence, 100=large influence) and with respect to their uncertainty (0=very uncertain, 100=very certain). For the simulation output, reliability is appraised (0=not trustworthy, 100=very reliable). *The boxes of the plot span from the first to the third quartile with the black cross line as the median. The dashed lines reach to the minimum and maximum values.* Source: Schmidter et al. (2017)

assess the impact of snow avalanches. The analysis of these texts clarified in what respect simulation results are useful and how the simulation process looks like in order to gain reliable results. Five categories could be determined with respect to the usefulness. Firstly, there is the advantage of having information on the *(i) spatial dilatation* of the process quantities. The simulation of avalanches allow to map endangered zones and punctual information can be transferred to the area. Further, the supply with *(ii) dynamic quantities* is considered as very useful for consultancy applications. Another aspect is the reconstruction or prediction of *(iii) rare events*. Here, the simulations are often the only available source of information. The *(iv) traceability* is appreciated, since simulation results can be traced back to the input data and parameter combination allowing a transparent reproduction of the results. The last category is the *(v)*

From the answers it was also possible to work out the requirements which are necessary to obtain useful results. Three main categories turned up: *(i) additional information*, *(ii) calibration* and *(iii) experience*.

For each of the categories mentioned above corresponding keywords were determined and their frequency in the answer text were counted. If one of the keywords were found in an answer, then the category is said to be mentioned. Table 1 gives an overview of the categories along with their keywords. In Figure 2 the results are illustrated. It is obvious that in terms of usefulness mostly the *spatial dilatation* (42% of the times) is mentioned as a benefit from simulating avalanches, which allows the user to map the spatial extent of the area affected. It is followed by the derivation of *dynamic quantities* (30%). These two categories probably represent the most interesting aspects for planning issues to address the driving question where and how intense does an avalanche occur. As requirement to obtain useful simulation results *additional information* are most frequently mentioned with 84% of the times. This high rate indicates that this category is an essential part to verify simulation results. The other way round, this could mean that in order to have reliable results they must be in accordance with other information on the simulated event. If such information is missing, the results have to be treated with caution.

Table 1: Categories of usefulness and their respective keywords found in the answer texts.

Usefulness in respect to objectives		**Requirements for usefulness**	
Category	**keyword**	**Category**	**keyword**
Spatial dilatation	Runout length, lateral spreading, spatial dimensions	Additional Information	Chronicles, documentations, silent witnesses, interrogations, etc.
Rare events	Rare events, missing data	Calibration	Testing different parameters, calibration
Traceability	Objectivity, traceability	Experience	Experience
Scenarios	Different scenarios, evaluate variations etc.		
Dynamic quantities	Design of structural measures, velocity, pressure, flow height		

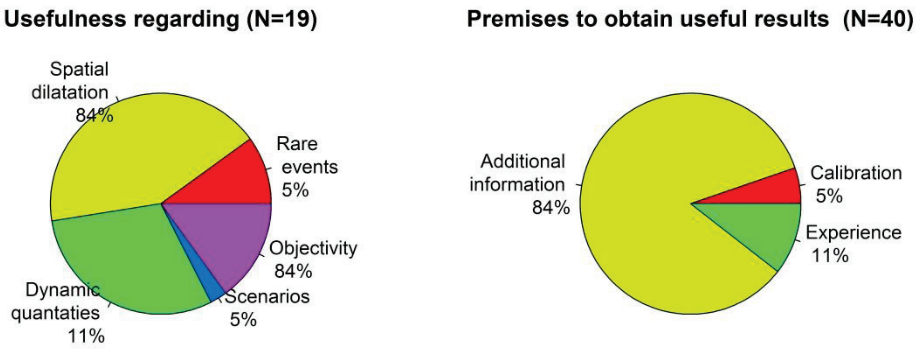

Figure 2 : Percentages of categories. The percentages are calculated by the ratio of hits for a specific category and the total hits for every category in the answered text.

In this case the other categories, *experience* and *calibration* could become more important.

At the end of the questionnaire an exemplified hazard assessment had to be examined based on the Gleirsch avalanche near St. Sigmund in Sellrain, Tyrol (prepared by the Austrian Avalanche and Torrent Control (WLV)). For that purpose a description of the location, an abstract of the avalanche chronicle, snow cover depths and release areas together with simulation results from Elba+, RAMMS::Avalanche, SamosAT and Alpha-Beta were given. Within the runout zone of that avalanche an alpine farm is located. The avalanches chronical indicates damages near the investigated location. Experts of the avalanche and torrent control delineated 4 release zones. Calculations with Elba+ and Samos used all release zones and included entrainment, whereas those with RAMMS did not explicitly include entrainment and used only one and two of the release zones. The Alpha-Beta model predicts an impact on the building, Elba+ more than 25 kPa, RAMMS more than 25 kPa for 2 release areas and less than 1 kPa for one release area. SamosAT predicts less than 1 kPa for the dense flow and 3-5 kPa for the powder avalanche. The experts interviewed were asked to estimate the impact pressure values for different faces of a building. The result of that inquiry is shown in Figure 3. Firstly, a fairly large scatter of the given values is noticeable, especially in case of the avalanche facing west facade. A clear distinction between the answers of the experts from Switzerland and Austria is evident. The median for the pressures given by participants from Austria is close to 10kPa, whereas the pressures given by the Swiss participants are around 30kPa. Here, a strong dependence of the selected values on the different national zoning regulation of the two countries is striking. It seems that the choice of pressure values is rather guided by the pressure limits of the respective hazard zone than by the results of simulations. In contrast, the values estimated for the other building facades including the roof are surprisingly similar. National regulations seems to mainly affect the choice of pressure values of the avalanche facing fronts, whereas the choice for the other faces is more based on the simulation results. For the other nation no conclusion can be drawn due to the low sample size.

3. CONCLUSION AND OUTLOOK

The survey clearly shows the importance of avalanche simulation tools for hazard assessment tasks. It seems that the application of simulation tools is a rising trend at least for the German-speaking countries, for which the participants of this interview can be considered as a representative group. Nonetheless, the experts insinuate that avalanche simulation tools are bound to uncertainties especially regarding the input data which are crucial for the reliability of the simulation result. The only exception is the digital elevation model, which is seen as very accurate. This reliability may be based on the widely-used application of DEMs derived from airborne laserscanning. The greatest challenge is the determination of the release area and the depth of the released snow. Both input parameters are hard to determine and are considered by the experts to have a high influence on the model result. The release depth is a good example where expert knowledge and new evaluation techniques may lead to a different perception: although the release depth is considered to have a major influence, qualitative studies by Oesterle et al. (2018) show that this may not be the case in an operational setting. In order to deal with the inherent uncertainties, the experts rate additional information as crucial: such as chronicles silent witnesses, field observation and the inquiry of affected persons. Moreover, the testing of different assumptions, the building of various scenarios and the expert's experience is seen to be essential. As Beisbart (2012) states, it becomes evident that "simulations do not produce knowledge like coffee machines produce coffee".

Rather it is the *user* who is producing knowledge by doing simulations, embedded in an extensive simulation process, including trials and errors, testing of different scenarios and including every available information that ultimately supports arguments for a certain judgment. Here, the expert is confronted with a difficult task. Bründl et al. (2010) point out, that the expert has to decide whether the simulation results provide additional information that are beyond the actual expert's knowledge of the investigated event or to reject them as not trustworthy. The difference between these two cases can be extremely small and a decision is always a judgment of the expert and therefore subjective to some degree.

Various approaches exist to take into account all available information to get an overall picture of the possible dangers connected with an avalanche. Simulation tools deliver one of these information, however as it could be shown, the local assessment and the expert's knowledge and experience is also of fundamental importance.

In this interview the focus was mainly put on the use of simulation tools. By looking at the results of this study new questions come up about the interaction of the different approaches, how an expert warrants the trustworthiness of these approaches and how the contribution of latent factors such as the expert's knowledge looks like. The realization of another survey could bring some valuable insights to these questions. A surprising result of that survey is the expert's estimations of pressure values for the Gleirsch alp house. National regulations for hazard zoning seem to have a higher influence on the expert's judgment than the provided simulation results. This assumption seems to be plausible, however, it is surely an aspect that is not entirely clarified and deserves further attention.

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