COOL TOOLS – WHITE RISK OFFERING NOVEL LEARNING AIDS

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ABSTRACT: Developing good trip planning and travel habits involves extensive training to balance key contributory factors for avalanche danger evaluation. However, some aspects are not intuitive and need coupling of physical processes for a better understanding. In order to train such complex situations, White Risk offers interactive training tools. Since winter 2013-2014 the web-based platform White Risk (www.whiterisk.org) provides comprehensive avalanche knowledge for both, beginners and professionals. Besides illustrative images, animations, movies and 3D-graphics, we developed interactive tools to challenge the users' skills, and allow training with immediate feedback. Here, we will point out four unique tools:

a) Pattern analyzer: The current avalanche situation can be analyzed based on four typical avalanche patterns. This tool gives a comprehensive guideline for an in-depth avalanche hazard evaluation.

b) Energy balance calculator: By regulating air temperature, wind, solar radiation and cloud cover, energy balance is simulated. The tool visualizes whether the snowpack or a human "experiences" warming or cooling.

c) Slab generator: This tool allows users to construct a multi-layered slab overlying a weak layer to learn more about triggering mechanisms.

d) Comparison of map to 3D-terrain: Transferring terrain information from topographic maps into real terrain is challenging for many backcountry users. An interactive tool offers a direct comparison between a map and a high-resolution 3D terrain model from different view angles.

These four tools will further foster our understanding of processes related to avalanche release and help us train our avalanche skills.

KEYWORDS: White Risk, avalanche education, avalanche formation, decision making, avalanche danger assessement

1. INTRODUCTION

The majority of avalanche accidents with people involved occur during off-piste or backcountry skiing. A promising way to reduce avalanche accidents is through a combination of appropriate avalanche forecasting and education. Therefore, the WSL Institute for Snow and Avalanche Research SLF puts a lot of effort into providing modern and attractive products to practitioners for both avalanche forecasting and education. One of these products is the new web-based platform White Risk (www.whiterisk.org; Harvey et al., 2013), available in German, French, Italian and English.

White Risk consists of three different parts. First, White Risk EXPLORE offers an extensive online resource for practical avalanche knowledge. This explorative part provides comprehensive avalanche knowledge for beginners and professionals alike. Illustrative graphics, animations, movies and interactive tools are designed to stimulate the users' interest. Second, White Risk TOUR is a trip-planning tool to organize backcountry trips online. Key data are provided to the mobile app White Risk for access en route. Third, White Risk PRO provides photos, graphics, animations and movies to build a customized presentation for avalanche instructors.

In this paper we will present four new White Risk tools that were recently developed. The main aim of these tools is to explain complex processes and to transfer scientific/expert knowledge on avalanche danger evaluation with a broader public. The four tools relate to: 1) typical

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avalanche patterns, 2) the snow surface energy balance, 3) the importance of weak layer and slab combination for avalanche triggering, and 4) terrain interpretation for trip planning and route selection.

1) Assessing avalanche danger requires balancing of many factors involving meteorological and snow conditions, terrain and human factors. In particular the evaluation of meteorological and snow conditions is challenging due to a large number of continuously changing factors and complex interacting processes. We therefore often use guidelines to recognize the most important contributing factors. In this case a classification of patterns of typical avalanche situations does the job and helps us focus on the main issues. By splitting for relevance we reduce the number of factors to be evaluated considerably and learn to form a sensible line of reasoning. Four patterns of typical avalanche situations are now widely used in avalanche education (Harvey, 2008 and Harvey et al., 2012). But some aid to figure out the importance of each pattern would be helpful.

2) However, some phenomena are not intuitive when assessing avalanche danger. High air temperatures and sunny weather, for instance, do not necessarily lead to significant warming or melting at the snow surface. In the end, it is the energy balance, the sum of all heat fluxes absorbed and emitted at the snow surface, which determines if snow melt will occurs (Armstrong and Brun, 2008).

3) Further, knowledge of dry slab avalanche triggering processes is necessary to assess avalanche danger. Dry slab avalanches start with a fracture in a weak snowpack layer below a cohesive slab (Schweizer et al., 2003). Thus, the interplay between the weak layer and the slab are recognized as key contributing factors to snow instability. Understanding the physical processes involved in slab avalanche release may improve our decision making in avalanche terrain.

4) Another difficulty for backcountry skiers is proper map reading skills and finding the intended route in alpine terrain. Especially transferring 2-D information from topographic maps to 3-D real terrain requires training.

Models and interactive tools can help to reveal the above, mentioned complex interactions. They can be used as training tools for practitioners. The web-based and interactive platform White Risk offers such intuitive tools to improve avalanche skills.

2. TOOLS

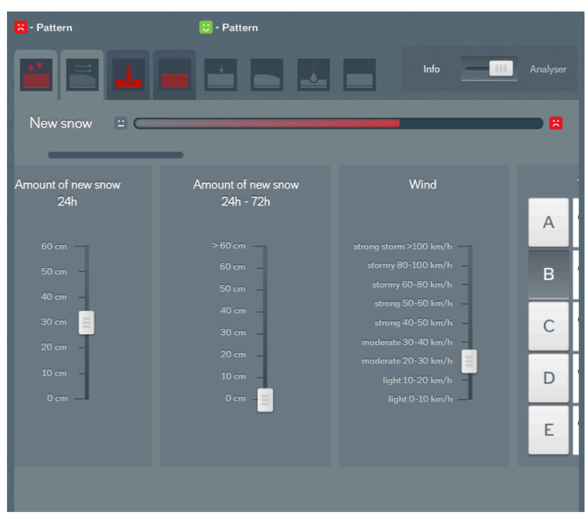
Digital media offer new ways of presenting and visualizing complex phenomena. The presented tools are a selection of many interactive features from White Risk EXPLORE (www.whiterisk.org). They focus on the following typical difficulties in the assessment of avalanche danger:

- Analyzing the main avalanche problem by combining observations: *Pattern analyzer*
- Effect of warming: *Energy balance calculator*
- Effect of snowpack properties on avalanche triggering: *Slab generator*
- Terrain interpretation from maps: *Transfer map to 3D terrain*.

2.1 Pattern Analyzer

Combining key contributory factors is essential to evaluate avalanche danger. For instance, strong winds will only build up wind slabs if there is enough loose snow to be transported. The pattern analyzer shows which key factors have to be observed to assess a specific avalanche problem. Depending on the selected observations a colored bar displays the evaluation of the avalanche conditions (Fig. 1). The tool is ideal to become more familiar with typical avalanche patterns and shows how the interactions of different factors affect the avalanche danger.

This tool is based on heuristic rules from expert knowledge.



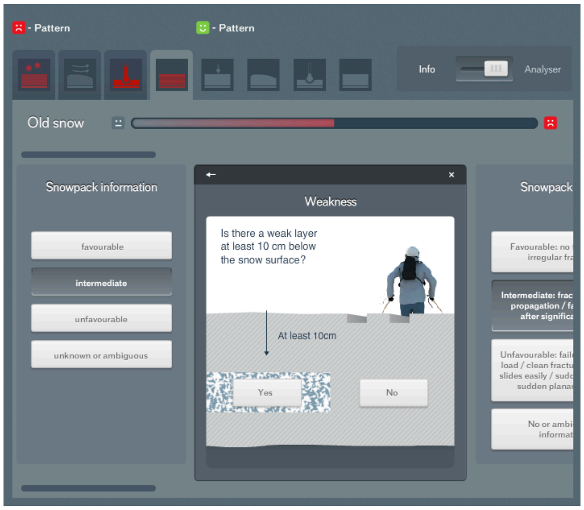


Fig. 1: Pattern analyzer: Adjustable rulers of key factors for a new snow situation (first image) and factors to assess during persistent weak layer situations (old snow pattern; second image).

2.2 Energy balance calculator

With this tool, well known meteorological parameters, such as air temperature, wind speed and cloud cover, can be combined to assess if the snow surface will undergo cooling or warming. Some of the combinations can be counter-intuitive, allowing the user learn how the energy balance affects the snowpack or a skier. By changing a ruler for each component or by selecting one out of the four specific situations, shown with the images above in Fig. 2, the resulting energy balance is calculated and visualized as a thermometer with heat fluxes as arrows.

The calculation of the energy balance (E) was simplified by the following sum of energy fluxes:

$E = S_{in} - S_{out} + L_{in} - L_{out} + H_S + H_L$.

S_{in} and S_{out} are incoming and reflected components of shortwave radiation, calculated from the regulated solar radiation. For snow we used an albedo of 0.8 for the skier 0.5. L_{in} and L_{out} are incoming and outgoing components of longwave radiation calculated from the regulated cloud cover and the snow surface temperature (TSS). L_{out} was calculated by using the Stefan-Boltzmann law with $L_{out} = \varepsilon\, \sigma\, TSS^4$, where σ is the Stefan-Boltzmann constant and ε = 0.95. The contributions of H_S and H_L were modeled according to Eqs. (2) and (4) given in Mitterer and Schweizer (2013) using air temperature, wind speed and snow surface temperature as input.

Fig. 2: Energy balance calculator in White Risk EXPLORE. The example shows a situation where the skier feels cold and the snowpack gets warmed up.

2.3 Slab generator

This tool allows users to construct a multi-layered slab overlying a weak layer to learn more about the effects of snow stratigraphy on skier-triggering. The user is asked to build a 40 to 54 cm deep slab consisting of four possible layers with different hardness and density. The slab may consist of a maximum of six layers. Further, one out of three different weak layers can be selected. The propensity of failure initiation, and crack propagation are then shown for the constructed configuration (Fig. 3).

The setup allows 3240 possible combinations, for which the following calculations were performed.

A simplified finite element (FE) model of static skier loading was used to calculate the stress within a weak layer according to Habermann et al. (2008). A stability criterion was calculated by $S = \sigma/\tau$, where σ is the compressive strength of the weak layer chosen according to the fracture energy of the weak layer and τ is the maximum shear stress at the depth of the weak layer calculated from the FE simulations. The stress τ was calculated based on the load of a skier without penetration. The propensity of crack propagation was derived by the critical crack size r_c calculated analytically (Reuter et al, 2014) from the anticrack model (Heierli et al, 2008). The snow properties were assumed from Schweizer et al.

(2011) and Scapozza (2004) and are shown in Table 1 and 2. All calculations were done for flat terrain.

Table 1: Assumed characteristics of the slab layers. h = depth of layer, ρ = density, E = Elastic modulus.

Slab layer	h [m]	ρ [kg/m^3]	E [MPa]
New snow	0.15	100	0.8
Soft wind deposit	0.15	150	1.7
Hard wind deposit	0.15	250	7.5
Melt-freeze crust	0.03	350	33.4

Table 2: Assumed characteristics of the weak layers. wf = specific fracture energy of weak layer and σ = compressive strength of the weak layer.

Weak layer	Example	wf [J/m^2]	σ [kPa]
Moderately weak	• Old faceted crystals	1	500
Weak	• Depth hoar • Large faceted crystals	0.5	100
Extremely weak	• Recently buried surface hoar • New snow	0.1	20

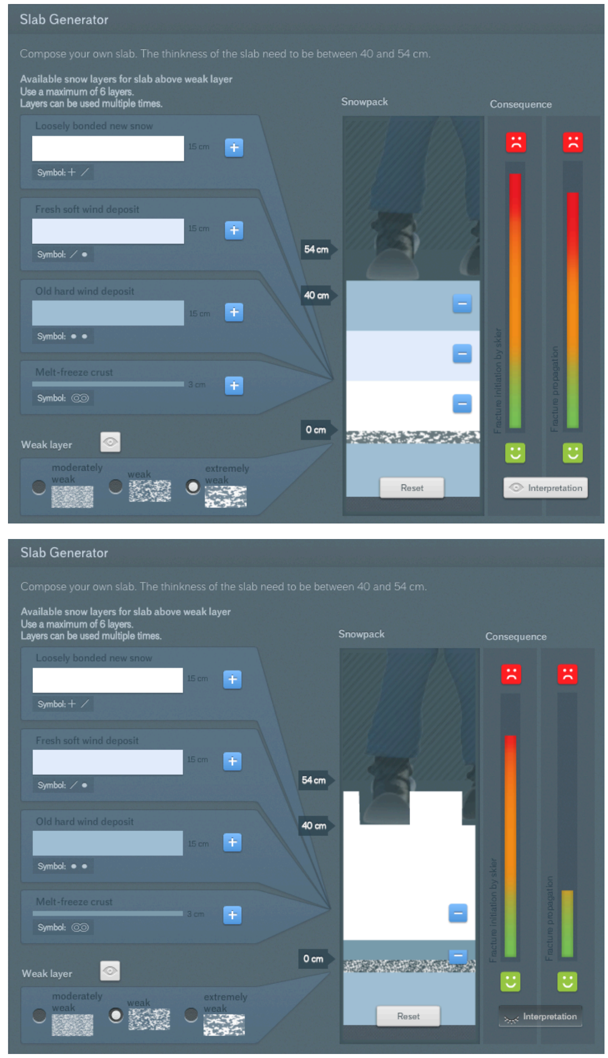


Fig. 3: Slab generator in White Risk EXPLORE. The first example shows a slab, which is dense at the top and soft at the bottom. The weak layer is extremely weak (e.g. surface hoar). This combination has a high propensity of failure initiation and crack propagation. The second example shows a predominantly soft slab with a crust at the bottom. The weak layer is classified as 'weak'. A failure is easily initiated, but a crack does not spread easily.

2.4 Transfer map to 3D-terrain

Interpreting terrain from maps is not simple, but essential for good trip planning and route selection. To train these skills, we developed an interactive tool offering a direct comparison between a topographic map and a high-resolution 3-D terrain model. The user can change the view angle and see the direction changing on the map as well as the 3-D image of the mountain. To give the terrain a realistic view a winter orthographic photo was wrapped over the high-resolution 3-D terrain model.

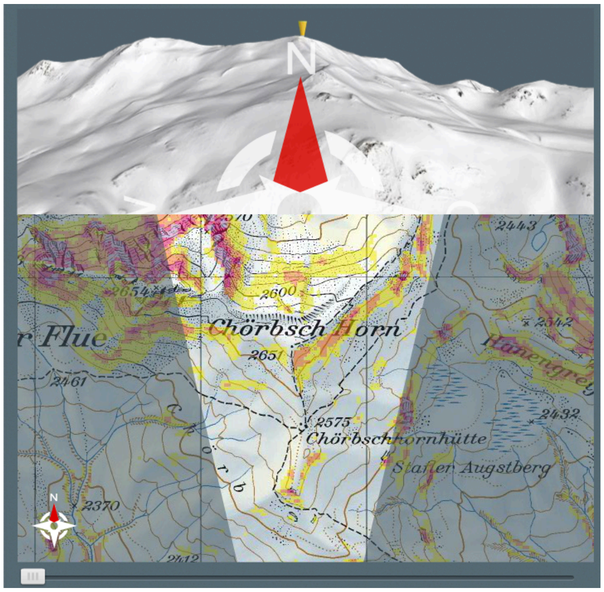


Fig. 4: Direct comparison of terrain between topographic map and realistic winter 3-D terrain. Viewing direction is north.

3. SUMMARY AND OUTLOOK

The presented White Risk tools allow users to train complex processes and interactions by playing with interactive features. Due to the immediate feedback, avalanche skills can be improved.

Under certain circumstances results from the tools are counter-intuitive. Especially then we can benefit and learn from them. If, for instance, you do not believe that the snowpack does not necessarily warm up while you are sunbathing, the energy balance calculator will give you the evidence.

The slab generator shows some interesting aspects concerning failure initiation and crack propagation from a theoretical point of view. It considers different layering of the slab and shows for instance, that slabs, which are denser at the top, are more prone to crack propagation than if the layering of the slab is the other way round. Further, this tool shows that the strength of a weak layer (specific fracture energy of weak layer) is important in terms of fracture initiation. We emphasize that this tool merely helps understanding the physical processes of triggering a slab avalanche in a schematic way. Neither different slope angles nor the dynamic fracture propagation are considered. In reality, additional parameters, including spatial variability and the tensile strength of the slab, play a crucial role for dry slab avalanche release. These properties are not included in this tool yet.

The presented tools certainly allow users to increase their process understanding related to avalanche release. Nevertheless, we emphasis that training outside in avalanche terrain is still essential, and cannot be replaced by any tools.

For the future we plan to include e-learning courses on the White Risk platform. Thus, users will be guided more strictly through relevant content and receive feedback on the exercises they are doing.

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