WSL Institute for Snow and Avalanche Research SLF

Research for People and the Environment

Imprint

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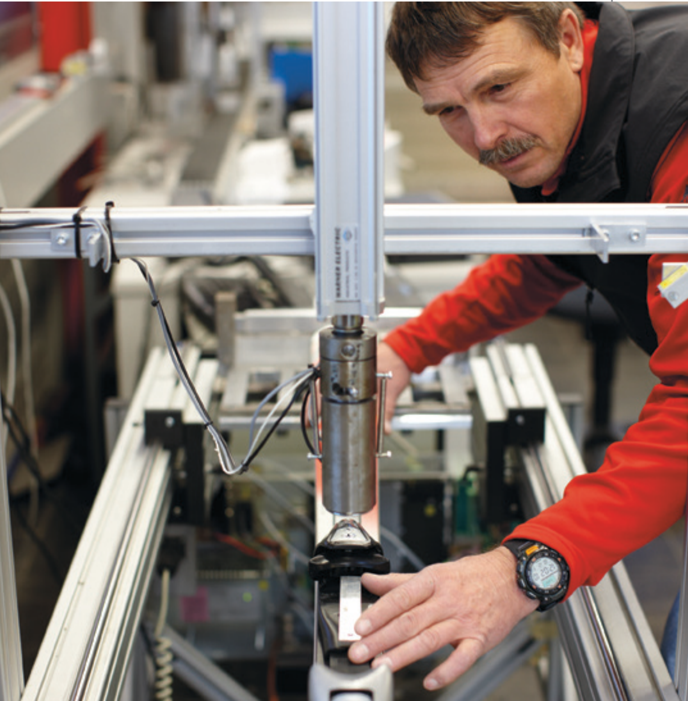
SLF at a glance

Research laboratory in the Alps

The SLF is an interdisciplinary hub of research and services in Davos. It is part of the Swiss Federal Institute for Forest, Snow and Landscape Research WSL, and thus part of the ETH Domain. Approximately 140 people work at SLF. As the institute's name denotes, their work is connected with snow and its interactions with the atmosphere, as well as the formation and dynamics of avalanches. Debris flows and rockfall, mass movements similar to avalanches, as well as permafrost and mountain ecosystems, are also part of the research fields addressed by SLF. In addition, SLF works towards optimizing protective measures in the framework of integrated risk management. A variety of services are also provided, including the avalanche bulletin, consulting services for avalanche protection measures, expert opinions on avalanche accidents, as well as the development of warning systems against natural hazards.

Building a bridge between science, practice and the public

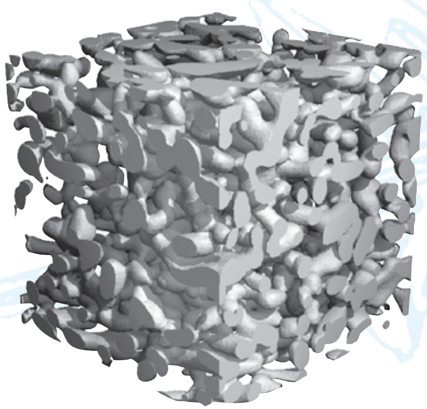
Linking science to practical applications is a long-standing tradition at SLF. Since 1945 the institute has already been in the advantageous position of being able to pursue both research and practical applications in parallel. In addition, SLF accords great importance to sharing its discoveries with the general public. For this reason, staff members pass on and elucidate their knowledge in a variety of publications, on public occasions and on the radio, television and Internet.



Snow from the laboratory

What do a complex leg fracture and the microstructure of snow have in common? Nowadays both are often examined using X-ray computer tomography. There are two such tomography scanners in the cold laboratory at SLF. They supply detailed three-dimensional data about where ice and/or air are found inside a snow sample, how snow crystals are interconnected, and how they are influenced and altered by changing temperatures. The physical characteristics of snow, such as thermal conductivity, elasticity and fracture behaviour can be calculated with these data.

Avalanche shovel



Microstructure of snow

The cold lab, with five different low-temperature chambers and one climate chamber, also has other advantages. It allows us to carry out experiments in precisely defined environmental conditions at any time of the year. We can thus answer specific questions posed by industrial partners, such as: How do car tyres react on snowy surfaces? How might the taste of ice cream be improved? How do diverse ski coatings glide over snow?

In one of the low-temperature chambers we manufacture our own snow whenever necessary. With the help of a special snow-making machine, water vapour is transformed into snow crystals exactly like those that fall naturally from the sky. These crystals are distinct from the artificial snow produced by snow cannons, which fabricate small, compact ice balls out of water, rather than filigree snow crystals. With the help of our snow manufacturing apparatus, we can even perform experiments in summertime with powder snow that is identical to the natural phenomenon.

Snow

Looking into the snowpack

No snow, no avalanches. And yet without snow, there is also no meltwater, no base for skiing, and no cooling effect through snow-atmosphere coupling. SLF focuses its attention on all these aspects of snow, analysing the structural constitution of the snow cover, either by digging snow profiles or with the help of the snow micro-penetrometer which was developed in the SLF workshop to measure the hardness of snow layers by means of a force sensor automatically driven into the snowpack. SLF also researches how much snow is deposited where, how the wind transports it, or how much energy the snowpack exchanges with the atmosphere. Such information is fed into a computer model called SNOWPACK that simulates the structure and layering of the snow cover – an important tool for avalanche forecasting services as well.

Determining the water content of the snowpack

In Switzerland, approximately a third of the overall precipitation falls as snow. Snow is thus the repository of immense amounts of water, making it an important factor in the overall water balance. Snowmelt is also a natural resource for producing electricity and replenishing the groundwater reserves in springtime. SLF investigates how much water is stored in the form of snow, where in the mountains it is, and the timing and quantities of its release as meltwater. Snow is not only of great economic significance for hydropower, but also in the tourism sector. The question of whether and where there will be sufficient snow for winter sports in future as a result of climate warming is of central importance. SLF endeavours to find answers to this. At the same time, it supports ski resorts in optimizing the preparation of their ski runs and develops faster skis for elite skiers.

From fracture to avalanche

Avalanches have small beginnings. Their origins lie in the highly porous structure of the snow. If the bonds between the individual grains of snow are few and fragile, there is a so-called weak layer. It can fail and collapse like a house of cards as soon as it is overloaded. Before a thick layer of snow breaks off and glides away as a slab avalanche, the weak layer needs to fail over a wide surface area. The crack is initiated at a certain point, e.g. beneath a skier, and propagates under the snow slab until the avalanche releases.

For the purpose of investigating this process, we carry out experiments in the field. Using high-speed videos, we can follow exactly how a crack occurs and then spreads, as well as how the snow slab deforms and moves during fracturing. This enables us to ascertain important snow characteristics contributing to avalanche formation and to evaluate the stability of the snowpack.

If we wish to forecast avalanches more precisely, we need clear, unambiguous indications of an avalanche whose release is imminent. The cracks that form in the snowpack, both before and during the triggering of avalanches, create sounds, just as other materials do when they break. For this reason we are examining whether avalanches can be predicted by acoustic signals inside the snowpack. Following verification of the method in the lab, initial field trials have shown that, in nature as well, the characteristics of the acoustic signals change just before an avalanche is triggered. If we succeed in recognizing those signals early enough and clearly enough, the technique may be useful in future as an early warning system for avalanches.

Avalanche blasting experiments

Avalanches

Protecting lives

Every winter, thousands of avalanches thunder downslope in the Alps. Many of them go unnoticed, and only very few cause damage. In settlements and tourist regions it is nevertheless important to protect human beings, buildings and roads against avalanches. SLF advises municipalities and ski resorts in Switzerland and abroad on the choice and construction of protective measures. It calculates the required stability of avalanche galleries, assesses avalanche risks for planned transportation systems, and evaluates locations and methods for the artificial triggering of avalanches, which is employed as a key precautionary measure nowadays by a number of public safety authorities. Equally important for avalanche protection is sustainable land use planning based on hazard maps, for which SLF has developed guidelines.

Avalanche research

The degree of success in warning about or protecting against avalanches depends on how well the dangers are understood. SLF explores how and where the various types of avalanches arise, and what prerequisites lead to avalanches that cause damage. In addition, scientists study the behaviour of avalanches along their route from a steep slope to the flatter terrain where they come to a standstill, how much dynamic power they develop along the way, and how fast they move. Not least because of this amalgamation of data and distillation of information, tourists and residents of the Swiss Alps can be reliably warned of the avalanche danger by the avalanche bulletin issued by SLF. Why, when and where avalanche are triggered is, however, not (yet) predictable in detail.

Rock fall in permafrost

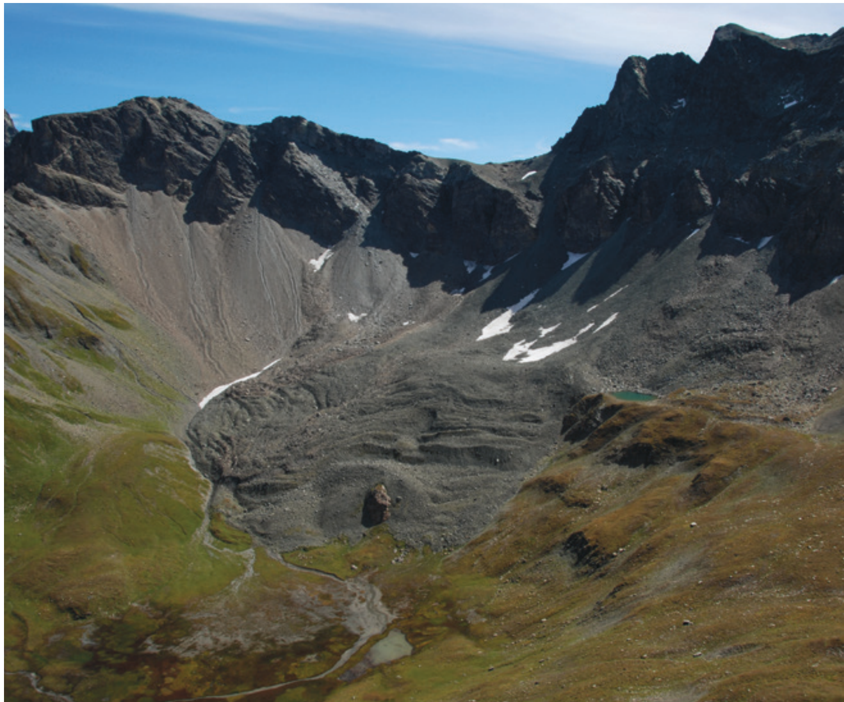
In a rock slope failure on the Piz Cengalo (canton Grisons) in December 2011, more than a million cubic metres of rock crashed down to the valley. In recent years increasing numbers of rockslides have occurred in other high alpine regions as well. There was frequently ice in the fracture areas – an indication of permafrost. We are investigating the role permafrost plays in rock slope failures and whether climate change can be expected to intensify these natural hazards in future.

In order to analyse the occurrence of permafrost, we have been measuring ground temperature in boreholes drilled as deep as 60 m since 1996. At the same time, we take measurements near the ground surface. Together, these indicate the degree to which air temperature fluctuations and snow depth have an influence on rock temperature, even in very steep terrain. These data are used to develop numerical models that simulate the conditions in rock walls. Thus we can estimate more precisely the conditions that lead to rock slope failures in permafrost.

In the Alps a variety of structures are built on permafrost, including cable-car stations, pylons, restaurants and avalanche defence structures. However, permafrost ice can creep and melt – particularly under the conditions provoked by climate change. To ensure safe and reliable functioning of the infrastructure, it is important to use specially developed construction and monitoring methods. In recent years we have therefore produced guidelines for the construction of avalanche defence structures in permafrost terrain and published a practical recommendation for other types of infrastructure.

Laser scanner

Golden hawksbeard



Mountain ecosystems and climate

Alpine wildlife habitats face new challenges

Icy temperatures, scarce food, short periods of vegetation, avalanches, snow loads – the inhabitants of the mountains have to master a host of difficulties. As a rule, fauna and flora have adapted well to these conditions. Changing land use and climate change, however, increase and intensify the challenges. SLF examines how mountain ecological systems react to these changes. In particular, it explores how mountain forests are expected to evolve in future and what measures will be necessary to continue to protect the population from avalanches and rockfall. Even the highest summits are of interest: Using both historic and recent vegetation records on 150 Swiss mountain summits, SLF is investigating whether and in what ways climate change has affected high alpine plants during the course of the last century.

Climate trends revealed by long-term snow measurements

Which winter sports will still be assured of snow in the future? Has an exceptional amount of snow fallen during the current winter? In collaboration with MeteoSwiss, SLF employs a network of observers who measure the amount of fresh snow and the overall snow depth daily during the winter. The majority of these measurements go back about fifty years, and some of the stations have delivered data for more than a hundred years. The long-term snow measurements not only serve as the basis for research queries concerning climate change, but also help to evaluate extreme weather events, calculate the appropriate dimensions for mountain infrastructure, and estimate potential floods.

Modelling natural hazards

RAMMS (RApid Mass MovementS) is a software package developed by SLF to simulate avalanches, rockfall and debris flows. It is the result of many years of research and development, as well as numerous mathematical and physical considerations: How is an avalanche structured? What happens when a rock bounces against the ground? How are stones and water mixed in a debris flow?

RAMMS simulates avalanches, debris flows and rockfall at specific spots in the terrain with a high degree of precision. With one mouse click, simulations are initiated; snow, rubble and rocks are set into motion on the computer monitor. These simulations provide useful information to those who wish to assess the danger to residential settlements or transportation routes and plan protective measures. Numerical models such as RAMMS can, however, only approximate real conditions. For this reason, a great deal of professional experience and expertise, along with data from each particular region, continue to be imperative in the estimation and evaluation of potential dangers.

In March 2010 we published the first version of RAMMS. Nowadays, practitioners such as engineers are using the software in over a hundred locations worldwide. To school the users in the application and handling of the software, we conduct workshops in Switzerland and abroad several times a year. We also continue to develop the software. For example, we are currently working on improving computer simulations of powder avalanches. This assists practitioners to estimate more precisely the pressure of the dust cloud. Apart from that we leave no stone unturned in our desire to improve the user interface and make it even easier and quicker to operate.

Danger sign

Prevention

Preventing avalanche risk

On average 25 people die in avalanches every year in Switzerland. Nearly all victims are killed while engaging in backcountry skiing, snowshoe tours or freeriding. And yet, even though more and more people are venturing off-piste, the number of avalanche fatalities has actually diminished slightly during the last 20 years, not least because of continuous improvements in avalanche prevention. An important contribution to prevention is made by the avalanche bulletin that is published twice daily by SLF. It is not only an essential basis for decision making in snow sports, but also for local avalanche and safety organisations. SLF is also heavily involved in other areas of avalanche prevention: it trains crisis management teams and public safety organisations and develops training aids such as the web-based avalanche prevention platform 'White Risk'. Numerous school classes also benefit from the avalanche expertise of the SLF during guided tours and prevention courses.

Predicting floods

Floods such as those that occurred in May 1999 made it clear how important snowmelt is to the hydrological regime in Switzerland. As a result of those terrible floods, SLF operates a snow-hydrological service (OSHD) today, which continuously monitors the snow water resources in Switzerland. This surveillance forms an integral part of the flood forecasting systems of the Federal Office for the Environment (FOEN). Since the OSHD and the avalanche warning system of SLF operate under the same roof, they can exploit useful synergies.

Test site Weissfluhjoch

Since 1936, employees of SLF have been conducting daily observations of weather and snow conditions near the Weissfluhjoch at 2,540 meters above sea level. The Weissfluhjoch test site is the only place in the world at this elevation where snow depths and fresh snow have been measured every day for nearly 80 years. From these long years of data collection we know that ...

- climate change has not yet had any influence on the wintertime snow cover at this elevation.
- annual precipitation amounts to about 1,200 mm, of which 75 % falls as snow.
- the greatest snow depth measured to date was 366 cm (9 March 1945).
- the snow depth on 1 January fluctuates between 38 cm (1949) and 222 cm (1975).
- the mean date of the onset of a continuous snow cover is 18 October (earliest 6 September / latest 25 November 1983).
- the mean date of the end of snowmelt is 9 July (earliest 3 June 1947 / latest 15 August 1983).

Particularly in view of climate change, such long-term data collection is worth its weight in gold. For this reason SLF attaches great importance to these daily observations and does its utmost to ensure that they are continued.

The test site is important not only for its data collection. Ease of access to the facilities and the numerous avalanche releases in the immediate surroundings also contribute greatly to groundbreaking research and analytical studies on snow mechanics, snow metamorphism, snow characterisation and measurement technology. In addition, prototypes of new instruments are tested, remote sensing methods are calibrated, and data captured at the site are used to compare our own and other researchers' snow cover models.

Snow overshoes

Snowshoe

History of the SLF

The beginnings of snow and avalanche research

Protection against avalanches was already a priority in the nineteenth century to Johann Coaz, the first Inspector General of Forests of the Swiss Confederation. His interest was focused on the prevention of avalanche release. From the 1920s, representatives of ski tourism, transport operators and hydropower plants stepped up their demand for scientific methods of avalanche research, and in 1931 they supported the founding of the Swiss Avalanche Commission. This was the first Swiss central agency that systematically studied avalanches. In order to better understand the processes that lead to avalanche formation and release, it was imperative to analyse the snow structure as well. To that end the very first snow laboratory was built on the Weissfluhjoch in 1936. In 1942, the Swiss Federal Institute for Snow and Avalanche Research was established. In 1945, responsibility for avalanche forecasting was transferred from the army to SLF.

Extreme winter marked a turning point

During the avalanche winter of 1950/51, ninety-eight people lost their lives in Switzerland. Suddenly there was an increased demand not only for basic research, but also for improved structural protection and intensified avalanche warning services. In 1989, SLF merged with WSL and has belonged since then to the ETH Domain. In the years that followed, the research fields of SLF were expanded further, to include debris flows, rockfall, permafrost and mountain ecological systems. In the avalanches that were triggered in Switzerland in February 1999, six times fewer people lost their lives than in the comparable extreme winter of 1950/51. This was proof positive that the efforts to improve avalanche protection had paid off.

Test sites

Instrumented steel wedge to measure avalanches

Avalanche tests

Studying avalanches in the field is dangerous. Experiments with huge, real avalanches are quite rarely carried out for that reason. When they do take place they are extremely elaborate and costly. Since 1997 we have been operating one of the very few avalanche test sites in the world, in the Vallée de la Sionne (canton Valais). When an avalanche rumbles down towards the valley, dozens of sensors measure a wide array of its characteristics, such as speed and impact pressure. In addition, a laserscanner in a hovering helicopter measures the surface of the avalanche path before and after an artificial triggering. From the difference between the two measurements, the amount of snow that the avalanche erodes or deposits along its track can be calculated. All these results help to improve our mathematical avalanche models and simulation programs.

Outdoor research laboratory at the treeline

The most recent research project at the experimental plantation on the Stillberg (canton Grisons) is an unparalleled investigation of the biosphere at the treeline. Over the course of nine years, mountain pine and larch trees were exposed to elevated levels of CO_2, similar to the concentrations that are expected to prevail 60 years from now. This experiment aims to test how alpine ecosystems will react to climate warming. The test site, which has been in operation since 1955, has already delivered significant insights from earlier experiments. Nearly 100 000 Swiss pine, mountain pine and larch trees were planted just above the treeline in 1975, and since then we have been continuously monitoring both their development and the evolution of their protective function, and observing which environmental factors have an impact on their growth and survival.

More about the SLF

Services and products

The most widely known service of SLF is surely the avalanche bulletin. But that is by far not the only service provided. SLF also publishes snow maps and weekly summaries of the weather conditions and snowpack changes that are relevant to the avalanche danger. It conducts risk analyses for roads and residential settlements, and produces safety concepts for local authorities and railway and cableway operators. In the aftermath of accidents or damage brought about by avalanches it writes expert opinions for courts and investigating authorities. On request it also provides a great deal of its data. In books, software packages, its own magazine DIAGONAL, fact sheets and its website, SLF condenses its extensive knowledge for practical purposes and presents it to the general public. Anyone who would like to have a look behind the scenes can take part in a guided tour at the institute or visit the exhibition in the lobby.

Training and education

SLF is deeply involved in educating and training young people. Each year it supervises about 45 master's degree candidates, interns and trainees, and offers approximately 25 students the opportunity to work towards a doctorate. Four apprentices receive training in information technology, electronics or polymechanics. Numerous employees pass on their knowledge at universities in their capacity as lecturers. Furthermore, SLF regularly organises conferences and courses that provide valuable continuous training and information sharing opportunities.

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