WSL MAGAZINE

DIAGONAL

FOCUS

Cold!

No. 1
18

Swiss Federal Institute for Forest, Snow and Landscape Research WSL

EDITORIAL

Dear reader
Brrr, the thermometer reads minus 17 degrees centigrade. That means putting on an extra layer before going to work by bike. Even snow researchers feel the cold, despite being used to standing for hours in a hole in the snow or in a cold laboratory, or to handling things in snow without gloves. But what is the relevance of research on cold, snow and ice during times of climate change? Is WSL moving its work to Antarctica because the snow in Switzerland is running out? Far from it, according to WSL's Director Konrad Steffen, and the ambassador Stefan Flückiger. WSL's knowhow is in demand for researching the effects of climate change. These are particularly evident at the Poles – with global consequences. But it is not merely snow, ice and permafrost that change when it gets warmer. Plants and animals are also reacting sensitively. Warmer is not necessarily better, and the effects are sometimes paradoxical – see page 16. When this Diagonal comes out, cold and frost will no longer be so topical – but I hope that this edition will nevertheless not "leave you cold"!

Dr. Jürg Schweizer
Head of WSL Institute for Snow and Avalanche Research SLF

FOCUS

Cold

KEY TOPICS

PORTRAITS

Photos: Cover: Stefan Margreth, SLF; Table of contents: Cold laboratory: Andy Mettler, swiss-image gmbh; One-Two: Martin Proksch, SLF; snowflake: Archive SLF; Alpine flora: Veronika Stöckli, SLF

REPORTAGE In SLF's cold laboratory, researchers experiment with snow from all over the world. This sometimes tests the ability not only of their instruments and materials to function in the cold, but also their own.

Cool research

Matthias Jaggi tests insulating material for his expedition to Antarctica.

Working at extreme temperatures requires warm clothes, such as a full-body down suit, thick gloves, thermal boots and lined hats.

SLF's cold laboratory, Davos (GR).

Photo: Andy Mettler, swiss-image gmbh

Matthias Jaggi is suffering. He is standing in the warm corridor in front of the cold chambers and trying to breathe life back into his bloodless hands. Slowly the stabbing sensation gives way to a tingling feeling and his stiff fingers thaw. "I've never had such bad frostnip before," says the 34-year-old mechanical engineer. He had briefly taken off his gloves because they got in the way while handling the equipment. He is actually quite used to spending several hours working in the cold. During the past few days, however, he has had to brave particularly tough conditions: in Chamber No. 4 in SLF's cold laboratory it is an icy –40 °C.

The cold laboratory enables the snow researchers to experiment with snow at any time of year under controlled ambient temperatures – regardless of how warm or cold it is outside. It consists of six chambers, each around 20 m² large and reminiscent of a walk-in freezer. The temperatures inside them can be adjusted as required. Most of the time they are between –25 and 0 °C. There is a good reason for Chamber No. 4 to be as cold as –40 °C: Matthias Jaggi is simulating polar temperatures.

The experiments that Matthias is carrying out in the laboratory are in preparation for his expedition to Antarctica. He will spend around three months at the Italian-French research station Concordia (Dome C), which is almost 1000 kilometres away from the coast and about 3200 metres above sea level. The temperatures there are certain to be cold: air temperatures in the central regions of the Antarctic are on average –54 °C. It will be Matthias' first time in Antarctica. "I am delighted to have this opportunity, and curious about what awaits me at the research station," he says.

Snow the whole year round

Matthias Jaggi has been working as a member of the technical staff in the Group 'Snow Physics' at SLF for nine years. He supports researchers in their projects and makes sure that, among other things, everything in the cold laboratory runs smoothly. Take, for example, Chamber No. 6, which is in operation all summer and winter. The refrigerator-shaped box seems at first sight unspectacular. But its appearance is misleading. Inside the apparatus, delicate snow crystals are hanging like ornaments on thin nylon threads. The 'Snowmaker' produces snow that is practically identical to that occurring naturally because, in principle, the same processes take place inside the machine as those in nature. Thanks to the 'Snowmaker', snow physicists are no longer dependent on snowfall for their experiments. They can, moreover, produce differently shaped crystals by varying the temperature and humidity. The machine can make about seven kilograms of snow per day – research material for studying, for example, physical processes in snow.

The Snow Machine in operation (in German): www.slf.ch/snow-machine

The cold chambers can also be used to store snow from all over the world. Researchers bring back snow samples from their various expeditions to analyse later. When storing these samples, the most important thing is to keep the temperature at around –25 °C. Under such conditions, the snow structures change slowly and the samples remain more-or-less intact in their original states. This is how they can be stored until the experiment proper starts.

One indispensable piece of equipment in the cold laboratory is the computed tomography scanner, which is well-known from human medicine. With such devices, researchers can scan the snow samples and reconstruct them in three dimensions to observe the so-called snow metamorphism (see page 13). During

Snow can be produced in the Snow Machine in SLF's Laboratory just as in real clouds: through the formation of crystals from vapour.

Photo: Mallaun Photography

this transformation, the snow changes its structure and thus also its physical properties. In the laboratory, researchers can reproduce this process, which takes places naturally, under controlled conditions. Their findings help them understand the structure of snow cover and the formation of avalanches better.

Snow metamorphism is also the focus of the experiments in Antarctica. The expedition is part of the SLF's joint project 'Snow properties evolution in a changing climate in Antarctica' with the Institute of Géosciences de l'Environnement in Grenoble and the French Polar Institute IPEV. The Antarctic serves as an important climate archive for the Earth. The analyses of ice cores allow conclusions about temperatures in the past to be drawn. Here snow metamorphosis is a factor that may well need to be taken into account when reconstructing earlier temperatures. In order to understand the interrelationships better, SLF's Research Group 'Snow Physics' wants to study the metamorphosis processes in polar snow cover under extreme temperature conditions.

Specially developed boxes

Matthias' break in the corridor to warm up is over. He slips back into his full-body down suit, puts on his lined hat and thick gloves and goes back into the cold chamber. On the laboratory bench is a block of snow. Matthias picks up a saw and, with just a few cuts, transforms it into the required shape. Franziska Roth, who is on work placement in the Snow Physics Group, joins him. Carefully, they together lift the roughly 40-centimetre thick block and lay it on silvery aluminium foil. It is vapour-tight and should prevent an exchange of the air in the snow block with the atmosphere. Later analyses should find out what effect this has on the snow structure and the isotopes in snow. Franziska and Matthias wrap the snow block up in the foil with practised hands. With experiments in the cold, it is sometimes the details that are decisive. For example, normal adhesive tapes only hold at temperatures above –10 °C. That's why

For more information on SLF's cold laboratory, see: www.slf.ch/coldlaboratory

Photo: Andy Mettler, swiss-image gmbh

Matthias Jaggi is used to working in icy temperatures. But even he has to warm up after work.

Matthias uses a special tape that sticks even under Antarctic conditions. He and Franziska then carefully place the packet inside a specially developed box.

After tests in the laboratory, the box will also be used in Antarctica. Inside, snow metamorphosis can take place under controlled conditions as both the lid and floor temperatures can be regulated. This enables Matthias to create a temperature gradient in the box between the top and the bottom. The larger the temperature difference, the faster the metamorphosis of the snow. In the Antarctic, Matthias will take snow blocks from a zone with untouched snow out in the open and then pack it into the metamorphosis boxes. He will also measure the temperature gradient in the natural snow cover in the field every day. He will then set the temperatures in the boxes to the same as those in the polar snow profiles – which means typically at about –45 °C at the bottom and –30 °C at the top. The boxes will be stored in an ice cave with a temperature of –50 °C. The snow in the boxes differs from the snow samples in the field only in being packed airtight so that no exchange with the atmosphere can take place.

Antarctic snow comes to Davos

In the meantime Matthias and Franziska are not at all unhappy to have almost finished the work. The cold has long made itself felt again: Matthias' nose is dripping and his glasses are misted over. Franziska's hair and eyelashes are covered with white frost. They quickly pack up all the material. Now the tests, which have taken several weeks, and the preparation in the laboratory are almost completed. Matthias considers them to have been successful: "The chances are good that the experiments will also work in Antarctica." Now the metamorphosis boxes just need to be shipped so that they can get to Dome C before Matthias.

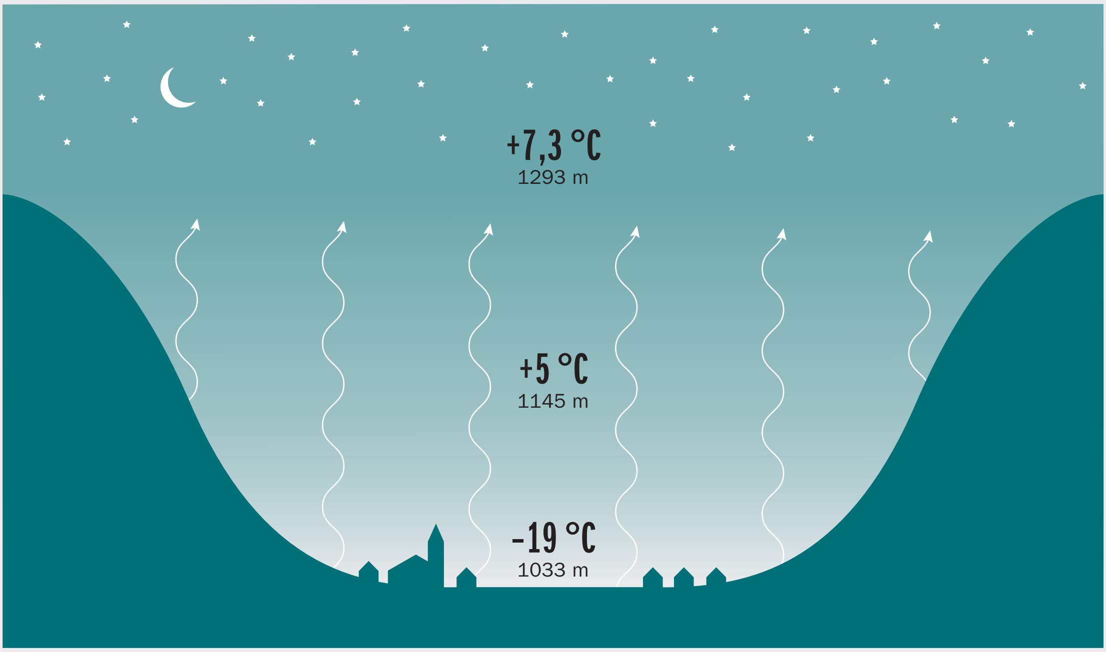
Matthias will only be able to take a few personal things with him for his three-month stay in Antarctica. Thick jackets, gloves and over-trousers all take up a lot of space. Nevertheless, he can't do without his running shoes. They have to go with him. He's already decided what he wants to do in his spare time: he plans to learn the programming language Python.

Once the expedition has been completed, the snow samples are shipped from Antarctica to Europe. Some of them will be sent to Paris, where French researchers will carry out isotope analyses. The rest will come to Davos. It is when Matthias gets back that his work will really start. He will use computer tomography to study the samples and analyse the snow structure. And where will he do it? Where it all started: in the cold laboratory at SLF. *(sni)*

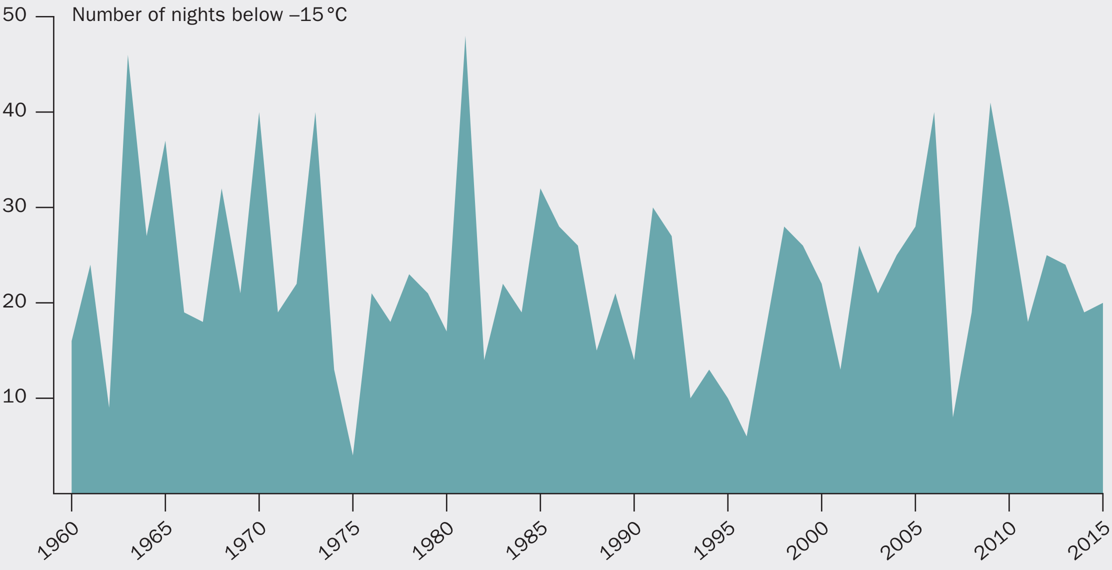
INFOGRAPHIC

‘Switzerland’s Siberia’ stays cold despite climate change

La Brévine in the Jura is the coldest place in Switzerland. On the night of 12 January 1987, the temperature there was a record –41.8 °C. During clear and calm starlit nights, the ground radiates heat upwards. At the same time, cold air accumulates like a lake in the closed valley. This leads to it becoming colder lower down than higher up. WSL researchers investigated how much temperatures in the valley and in the surrounding hills differed during the winter 2014/15. The largest difference they found was a good 26 °C.



Ice-cold nights occur in La Brévine just as frequently today as they used to – despite climate change. The high-pressure weather (anticyclones) responsible for the bright and starry nights still occur, and the small village in the Jura maintains its reputation as the Siberia of Switzerland.



Infografik: Raffinerie/WSL; Data source: Vitasse et al., 2016

The change in the glacier's volume allows them to establish how much meltwater flows down into the valley and can potentially be used for energy production.
WSL researchers use a drone to take aerial photos of the glacier. They merge the images and link them to GPS data to produce a 3D-model of the glacier's surface.

Recording data on the Findel Glacier (Canton Valais).

Involvement in the Arctic. The melting ice in the Arctic has far-reaching impacts – also on Switzerland. WSL's director Konrad Steffen and the ambassador Stefan Flückiger discuss climate refugees, the Arctic Council, and the race for raw materials.

Stefan Flückiger is Head of the Sectoral Foreign Policies Division in the Dept. of Foreign Affairs and represents Switzerland in matters concerning the polar regions.

Konrad Steffen, the Director of WSL, has been doing research in the Arctic and Antarctic for 40 years, where he has been investigating the effects of climate change.

Switzerland is far away from the Arctic but is nevertheless directly involved in research there. Why?

KS: There are many parallels between the polar regions and the Alps. Snow, glaciers and permafrost can be found in both, but at different altitudes and in different dimensions. Research into such phenomena first began in the Swiss Alps, and many of today's methods and measurement instruments were developed in Switzerland. This know-how can be used in polar research to find out, for example, more about what is happening to the ice masses in the Arctic.

Why is this important?

KS: If the large glaciers in Greenland melt due to climate change, the sea-level will rise further. Although this has no direct influence on land-locked Switzerland, indirectly it affects us greatly. It means that in coastal regions, particularly in Asia, many mega-cities will be submerged and thus become uninhabitable. This will result in streams of refugees, also towards Europe, where the standard of living is high.

How are politicians reacting to such forecasts?

SF: In politics, there is currently a fast growing awareness of the social impacts of climate change. Clearly, the global developments will also affect Switzerland. We cannot allow ourselves to ignore this. To prepare ourselves, we must understand the origins and interrelationships. This is where we need to rely on findings from research. For politicians, the task is to use these findings as much as possible to minimize the risks of climate change.

Switzerland has been a member with observer status of the Arctic Council, set up by the countries bordering the Arctic, since 2017. What were the motivations for becoming a member?

SF: The political importance of the Arctic is increasing. With the melting of the sea ice, new shipping routes have suddenly opened up, which shorten the time it takes to transport goods between Asia and Europe by a third. Enormous oilfields and mineral deposits have now become accessible and new fishing grounds in the Arctic Ocean can be exploited. It's therefore essential to clarify who these resources belong to and who may use them. Even countries far from the North Pole are declaring their interest. Thus China, Japan, India and Singapore have had observer status on the Arctic Council, which advises on the use of the Arctic, since 2013. The Federal Council realised that Switzerland should not

Photos: put at disposal

The Swiss Camp in Greenland: This is where researchers at WSL spend several weeks each year studying the effects of climate change on the Arctic ice masses.

miss out on this development, and started its application to the Arctic Council in 2014.

Stefan Flückiger and Koni Steffen, you led the application campaign together. How did you find the cooperation?

SF: From my point of view, this is an ideal example of how research and politics can work hand in hand together. We really needed support from research for this undertaking. Koni's many international contacts, which he has built up during his work over the years, were very valuable. What was also crucial for the success of our application was that Switzerland's Arctic research has a very high reputation internationally. Its good standing is extremely important for Switzerland's policies.

KS: For me it was good to see how interested politicians are in our research results. This shows how relevant they are for society.

What benefits does being a member of the Arctic Council have?

KS: As researchers, we have been active for years in the Arctic Council's various workgroups that are especially scientifically oriented. It's new, however, for us to also have support for this work from politicians. This has increased the visibility of our scientific work.

SF: For Switzerland to be granted observer status is a sign of great recognition. Greece, Turkey and the EU applied at the same time and were rejected. Switzerland's application was accepted because it has not lodged any territorial claims in the Arctic and is, moreover, well

Photo: Konrad Steffen

"In politics, there is currently a fast growing awareness of the social impacts of climate change."

More information on research in eternal ice: www.wsl.ch/ice

known to be a reliable international partner. We were also able to convince the members of the Arctic Council of the high quality of Swiss research in the Arctic.

KS: I also think that Switzerland can, as a neutral country, act as a mediator when it is a matter of reconciling the interests of different countries.

But the application was surely not completely unselfish. What kind of economic interests is Switzerland pursuing here?

SF: One of the main tasks of Swiss foreign policy is to promote the Swiss economy. Having the status of an observer on the Arctic Council is useful in this respect as well. Switzerland is one of the most important locations for companies trading in raw materials. Should they want to be active in future in the Arctic, we can help them. We are, of course, aware of the international discussion about policies for raw materials. This is precisely why politicians will try to hold talks with such companies and assume a regulating role in terms of sustainability. Exactly what form this takes, however, will only become apparent in the future.

How strongly must the Arctic be protected?

KS: Complete protection like that in Antarctica is, I believe, not possible because Norway, Denmark, Russia, the USA and Canada already own and use parts of the Northern Arctic Ocean. We cannot prevent other countries also wanting to benefit from places where the ice is now melting. Using the new shipping routes even has advantages: Since they are much shorter, less fuel is needed, which helps the climate. It is, however, important to make sure the Arctic is used sustainably.

SF: That's something I also consider essential. I don't believe it is just empty talk. Environmental awareness has, in the meantime, increased tremendously everywhere. It used, however, to be different. You notice this when you see, for example, the heavily polluted Russian coast and how it was forgotten after the Soviet Union collapsed. The newly awakened interest in the Arctic can also provide an opportunity to clear up such contaminated sites and do things better in future. *(cho)*

SNOW PHYSICS **Cold research on 'hot' material.** Snow is a strange substance. From a physical point of view it is not at all cold – it is hot. Its changeability keeps not only snow physicists and avalanche researchers on the go, but also ski designers and tyre manufacturers.

The starting point is a dust particle in a cloud – a condensation nucleus around which steam accumulates and freezes to form a snow crystal. If several such crystals combine, a snowflake is born. The flake – a star-shaped formation containing around 100 trillion water molecules – swirls down to the ground and lands on other snow crystals.

What looks like a cuddly blanket draped over the silent winter landscape is, according to recent findings in snow research, an extremely changeable matter: No sooner has our snowflake landed, than it begins its metamorphism. "Snow behaves differently from most other material, which makes researching

Photo: Jürg Schweizer, SLF

Strange behaviour: Snow can creep like thick dough.

it particularly exciting," explains Martin Schneebeli. He is head of the Research Group 'Snow Physics' at SLF and has been studying the changeability of snow in a laboratory where the influence of factors such as temperature, pressure and friction can be investigated separately.

A 'hot' material

At temperatures far from its melting point – for example, at –100 °C – snow doesn't change much. But the closer it gets in temperature to its melting point, the more mobile the molecules in the snow crystals become. Since the temperature of snow on Earth is never very far from its melting point of 0 °C, it is, from a physical point of view, actually a 'hot' material. "This has an enormous effect on how the material behaves," says Martin.

The snowflake merges with other ice crystals at their points of contact, i.e. it sinters, forming ice bridges that hold the snow layer together better. This is how powdery new snow turns into stable old snow. If it weren't for this sintering process, the preparation of ski pistes, for example, would be impossible because no hard surfaces with a good grip would be formed. "This works best with small snow particles from which a lot of water vapour can escape," explains Hansueli Rhyner, Head of SLF's Research Unit 'Snow Sports'. This is the case with artificial snow, or technical snow as the experts call it. It is therefore better suited for preparing pistes than natural snow.

For further information, see: *www.slf.ch/snow-substance* and: *www.slf.ch/snow-metamorphism*

Another special physical property of snow is its relatively high vapour pressure. This means that water molecules like to turn directly from their solid into their gaseous state. At colder spots, the molecules that have evaporated then cling again onto other ice crystals. In the process, new crystal structures may form. For example, cup-shaped and platelet-like crystals, known as surface

Researchers use the SnowMicroPen to measure the layers in the snow cover quickly and accurately.

Photo: Jürg Schweizer, SLF

hoar crystals, form those dreaded weak layers in the snow cover that are prone to develop into avalanches.

Snow encourages creativity

Detecting such weak layers is crucial if you want to estimate the risk of avalanche release. One way of doing this is to inspect snow profiles visually and assess them by hand. Digging them out is sweaty work. Assessing snow profiles is still important for stability tests, but having a look inside the snow cover can be done more quickly and accurately today using the SnowMicroPen (a high-resolution penetrometer) developed at SLF.

The portable probe is placed on the snow surface. The tip bores into the snow and records the boring force required every four micrometres. Each layer, for instance, a thin ice crust, hoar crystals or new snow, produces a different force-distance signal. This makes it possible to measure over larger areas the properties of the weak layers, which are often just a few millimetres thick. “The instrument is now standardly used in assessing snow cover,” says Martin.

Snow researchers have taken over one technology from medicine: micro-computed tomography (micro-CT), with which tissue can be assessed without destroying it. A CT scanner was specially adapted for snow in SLF’s cold laboratory, and can be used to observe the transformation of snow probes ‘live’ over longer time periods and determine the spatial arrangement of ice and air in snow precisely. The data can also be used to check, for example, the accuracy of snow-cover models.

The colder it is, the more the friction

Wherever snow is involved, its mutability puts technology to the test. Winter tyres, for instance, must have the best possible grip in snow with different consistencies at variable temperatures. SLF researchers therefore have developed a machine specially to study the friction between rubber and any kind of snow more precisely. Tyre manufacturers use the resulting data to develop better winter tyres.

Skiing as a sport also depends on the snow’s ‘mood’. If it is too warm, a wonderful carving piste gets turned into slushy snow. If it is too cold, it slows skiers down: “The colder the snow, the more the friction,” explains Hansueli Rhyner. The optimal temperature of snow for skiing is between –3 and –5 °C because then the film of water that the skis glide on is ideal.

Our snowflake has therefore turned back into water under the skis. ‘Hot’ snow is always close to its melting point, which makes it fascinating for snow researchers, but also poses a challenge. They are, however, working out, step by step, the secrets of this mutable natural substance. Their findings should, in the end, be of benefit not only for avalanche protection and climate research, but also for the car and snow-sport industries. *(bki)*

REPORT **How plants adapted to cold react to climate change.** Mountain and tundra plants are particularly severely affected by climate warming. Researchers at WSL are studying how the vegetation is changing.

Temperatures below freezing with icy north-east winds and snow – such conditions are challenging for plants that want to brave them. Unlike many animal species, they cannot escape the winter or seek protection from it somewhere. Only those that are frost-resistant and well-adapted to the cold climate can survive.

The temperature therefore largely determines where particular plant species become established, as well as how they grow and reproduce. Due to climate change, however, temperatures are increasingly on the rise. What does this imply for the vegetation composition – especially in mountain regions, where the warming taking place is twice the worldwide average? How are the cultivated plants and forest trees at our latitude reacting to the higher temperatures?

More frost damage despite climate warming

Researchers at WSL and SLF are pursuing these questions in several different projects. For example, one group, led by Yann Vitasse and Martine Rebetez from WSL and the University of Neuchâtel, has been investigating, with the support of FOEN, the Swiss Federal Office for the Environment, whether late frosts are becoming less frequent in Switzerland with climate change and, correspondingly, whether the risk of frost damage is declining. To this end they analysed, together with Christian Rixen from SLF and researchers from Agro-

Investigating the vegetation in one of the warming chambers in Val Bercla (the Grisons).

Photo: Archive SLF

Only plants adapted to a cold climate like *Ranunculus alpestris* can survive in the mountains.

scope Conthey, long-term data from automatic weather stations. The research team also evaluated thousands of observations made by laypeople about the leaf-out dates of beech and spruce, as well as the flowering time of apple and cherry trees. The results indicate something unexpected: although the growing season for vegetation is starting earlier, the last late frost at higher elevations is generally not occurring earlier in the year despite climate warming. This means that the risk of young leaves and flowers above 800 m a.s.l. being exposed to a spring frost is increasing – and it could increase further in the future. These tree species are likely, in the long term, to be affected by a late frost more frequently than they are today. The findings, however, also show that it would not necessarily be a good idea to promote varieties of fruit and forest tree better adapted to an ever-warmer summer climate as they often start their growing season earlier in the year and are thus particularly susceptible to frost.

Summit climbers are on the increase

In another project, SLF is investigating how climate warming is affecting plant composition on mountain summits. Christian Rixen and Sonja Wipf cooperated with researchers from all over Europe on mapping the plants growing on different summits in the Alps, the Pyrenees, the Carpathians, as well as in the Scottish and Scandinavian mountains. They compared their surveys each time with up to one-hundred-year-old data from the same site. Their results show not only that the number of species on mountain peaks throughout Europe has increased, but also that this increase is taking place at an ever faster pace. The reason for this is that the climate is warming increasingly rapidly.

More information on the summit flora: *www.slf.ch/summit-flora*

The higher temperatures enable species from lower lying meadows to expand their distribution range upwards. Another effect of climate warming is that many plant species already growing on the summits are also becoming

Photo: Thomas Stucki, SLF

more widespread. But not all plants are benefiting: several high-mountain specialists have decreased or even completely disappeared. Christian: "It remains to be seen whether the species from lower elevations that are competitively stronger in the long term will displace the specialists high up completely."

Flowering seasons are becoming more similar

The SLF team are not only monitoring these climatically determined changes in the Alpine vegetation on the basis of historical and recent vegetation surveys. Christian and his research colleagues have also maintained the Swiss site of the International Tundra Experiment ITEX in Val Bercla in the Grisons since 2009. In this large project, research teams are performing long-term experiments in Arctic, Antarctic and alpine habitats at over 40 sites worldwide. By generating higher temperatures in warming chambers – similar to open-top greenhouses – they investigate how the simulated climate change affects the vegetation.

Christian and his team are not, however, just responsible for their own site, but are also involved in the worldwide evaluation of ITEX data. In their latest publication, they analysed long-term data on nearly 50 tundra plants from 18 sites ranging from Alaska, Spitzbergen to the Faroe Islands. The average summer temperatures at these sites range from 2.8 °C to 11.9 °C, and thus replicate a climate gradient. At all these experimental sites, researchers studied, among other things, when the plants developed leaves during the year, when they started to flower or when the leaves began to fall. This showed that all the species studied reacted more strongly to the higher summer temperatures at the colder sites than at the warmer sites, and that the dates when the leaves and flowers opened shifted to earlier in the year more in the North than further South. "We assume that the flowering season of species from northern regions is increasingly aligning itself with those from southern regions," says Christian. If the sites are not located far apart, insects and wind can transfer pollen from flowers further South to the North, and vice versa. This then intensifies the gene exchange between these regions.

For further information on the tundra experiment, see: *www.slf.ch/itex-en*

These results, like the studies of summit flora, show that the vegetation in cold regions has already altered with climate change – and will continue to change, even though the direction in which the species composition will shift is not always clear. *(chu)*

Christian Ginzler, Birmensdorf

"It's quiet and peaceful around our house in Uerzlikon. Here you can smell the countryside. Lying in my hammock I can hear the cows grazing, and can completely switch off."

THE VIEW FROM ABOVE

What's the state of the forests, bogs and spawning waters for amphibians? How are these habitats changing? For large areas, such questions can best be answered by having a look from above. Special cameras and sensors record information about the earth's surface from aeroplanes or satellites. Christian Ginzler's Remote Sensing group evaluates the resulting data. "With remote sensing you can see things that are hidden to the human eye."

Photo: Bruno Augsburger, Zurich

FOREST

Taking a look at the metabolism of trees: What happens under drought stress?

On the same eye level as the tree-tops: To enclose the tree, the researchers use metal scaffolding 12 metres high.

"Let's go!" Via radio Arthur Gessler gives the go-ahead for an experiment that, to date, is still unique. He slowly opens the control valve of a gas cylinder. Gas flows through tubes into the plastic enclosure around a Scots pine. For three hours the tree, which is packed airtight from top to bottom, is forced to absorb the gas and incorporate it into its metabolism. The gas is CO_2 marked with a stable ^{13}C isotope.

After the three hours, Arthur stops the inflow and the tree is unpacked again. Now the first measurements start. "We can keep track of when the marked CO_2 reaches the tree's leaves, stem and roots during respiration," says Arthur. He is an ecophysiologist at WSL and is in charge of the large-scale experiment, which has researchers participating from Switzerland, Germany, Finland and China.

The experiment is taking place at the end of August 2017 in the Pfynwald near Leuk (Canton Valais), where it is hot and dry, and where many pines have died. The researchers suspect the mortality is due to a combination of heat, drought, pests and tree diseases. In order to understand the processes in detail, they are investigating the metabolism of the trees.

Tracking the sugar

The experiment will show whether the trees suffering under drought stress produce enough sugar in their

Photo: Gottardo Pestalozzi, WSL

needles and whether the transport of the sugar to their stem and roots, as well as further into the soil, still functions. During a dry period, the trees close the microscopically small stomata in their leaves and needles to minimise the loss of water to the atmosphere. This leads, however, to the tree taking up less CO_2, which means it can form less of the sugar that is produced from CO_2 through photosynthesis. To have a basis for comparison, the researchers are performing the same experiment with some of the 500 pine trees that WSL has been irrigating in the Pfynwald since 2003 to investigate the effects of drought and irrigation on pine forests.

Using portable laser spectrometers, the researchers can determine directly on site the moment in time when the marked carbon reaches different parts of the tree. The analyses of the plant material in the lab will show what happens to the sugar formed. Normally, some of it is used to create defence compounds like resin. If not enough sugar is available, the tree will lack these substances and will be more susceptible to pests such as bark beetles. This could explain why the trees die during drought. Since 2017, it has been possible to carry out analyses in a well-equipped isotope laboratory in Birmensdorf with the four mass spectrometers that WSL was able to take over from the Paul Scherrer Institute (PSI).

Everything is linked

In this experiment, the researchers also want to investigate whether the tree passes on the sugar it produces to, for example, seedlings, which are particularly vulnerable to drought. The roots of the forest trees are linked via a network of fungal hyphae that can transport various compounds. Soil specialists analyse how far the sugar produced from marked CO_2 is distributed in the soil via such hyphae and whether it also reaches the soil microbes.

Arthur Gessler is satisfied with the day in the field as he and his team were able to collect the samples they required. The evaluation of the data will now take some time, but afterwards the researchers will understand better why the pines in Pfynwald are dying. This will provide an important basis for estimating how the forests will develop in a warmer and drier future. *(lbo)*

www.wsl.ch/pfynwald-en

This is where the marked CO_2 respired by the enclosed tree collects.

Photo: Gottardo Pestalozzi, WSL

FOREST

WSL surveys show: Recreational forest conflicts successfully resolved

The separate bike trail on the Uetliberg enables bikers and hikers to share the Forest safely.

More and more people live in peri-urban areas. This has led to greater pressure from recreation-seekers on the forests close to the city. Conflicts sometimes develop among different groups of visitors, as happened in the Üetliberg Forest, where until 2005 hikers and mountain bikers were increasingly getting in each other's way.

As a measure to deal with the conflict, the City of Zürich 2005 built a bike trail to keep the bikers on a separate route. WSL carried out surveys on the Üetliberg before and after it was constructed. The results show that the trail helped to defuse the conflicts between the hikers and the bikers. This was confirmed by the third survey WSL carried out in 2017: Visitors' satisfaction with the time they spent in the Forest was even greater than eleven years previously. In particular, being disturbed by bikers was mentioned less frequently even though more of them were using the Forest. The measures taken also continued to be viewed positively. Only the ban on transporting bikes on the Üetliberg Railway was rated significantly worse than in 2006. The bikers moreover said that sometimes too many of them were using the trail, and the advanced bikers wanted more challenging trails. The downhill bikers could not, however, be interviewed because the bike-transport ban has led to them no longer using the Üetliberg much. The overall satisfaction of the visitors with the situation on the Üetliberg could also be connected with the lack of responses from downhill bikers. Nevertheless, WSL's evaluation has shown that the measures taken have been successful. *(rlä)*

Photo: Zurich Tourism

Dimmable LED street-lamps help hard-pressed night-lovers

Artificial light sources can be deadly traps for insects that are active at night: They circle round the lamps until they die of exhaustion. Can reducing the duration or the brightness of the street lighting help to keep down the losses? How does this influence insect-hunting bats? WSL biologists working with Janine Bolliger tested this with the help of the EKZ (Elektrizitätswerk des Kantons Zürich EKZ), Canton Zürich's municipal electricity utility, who installed sensor-controlled LED street lighting in Urdorf und Regensdorf. When no cars are driving past, the lamps automatically dim their light by about two thirds.

Less light means fewer victims

During the pilot phase in the summer of 2017, the lighting system was set to alternate at weekly intervals between dimmed and full lighting. Traps were mounted on the LED lamps to catch flying insects while a recording device registered bat calls. Early each morning a WSL staff member collected the insects.

It was the weather – in particular the temperature and precipitation – that was found to largely determine the number of 'night lovers'. But dimming the lighting also had an effect: the number of trapped insects and bat calls dropped to half those with full lighting. Bugs, moths and hymenopterae are especially sensitive to light at night, whereas flies, mosquitoes and beetles are less affected. For bats, usually only the most common species benefited from the well-laden table around the lamps, while more sensitive species did not venture into the light. Janine's conclusion: "Dimming street lamps and leaving them on for shorter periods of time can help to make well-lit streets less harmful for creatures active at night." *(bki)*

Insect trap mounted on an automatically dimmable LED street lamp.

Photo: Martin Obrist, WSL

LANDSCAPE Strategic spatial planning as the key to guiding the development of urban areas in Europe?

The numerous urban areas in Europe have, despite all their differences, one thing in common: They are all becoming larger. This apparently unstoppable process is mostly at the cost of natural and semi-natural landscapes. As a consequence, new residential areas are replacing fields and meadows; and new motorways, airports and industrial plants are dissecting the habitats of rare plant and animal species, as well as recreational landscapes.

Copenhagen is developing its centre with contemporary-style buildings.

How far is it possible to steer these developments in a positive direction? This is what researchers have been investigating in the research project CONCUR, which was started in the year 2016 and which is financed by the Swiss National Science Foundation through its funding line 'Consolidator Grants'. WSL's landscape researcher, Anna Hersperger, and her international team want to find out how strategic spatial planning is changing Europe's urban regions. Even though planning is taking place everywhere at local, regional and national levels, we still know little about how strategic spatial planning really affects the spread of residential areas and transport infrastructure. The results of this large project should shed light on the jungle of steering options for urban development in Europe.

The WSL team has investigated during the past two years strategic spatial plans and planning processes in 21 regions between Barcelona and Stockholm and between Vienna and Edinburgh. The researchers interviewed more than one hundred specialists in strategic spatial planning across Europe from research and practice. At the moment, the project team is analysing how the different urban regions approach strategic spatial planning and how well the administrations in particular regions are in a position to implement the plans. On the basis of this comparison, the researchers are developing a generalised understanding about which actors and processes in administration and politics shape strategic spatial planning. In the second half of the five-year project period, the researchers will introduce strategic spatial planning as a factor into a land-use model that takes into account all forms of built, managed and natural uses. Up until now, planning activity has rarely been includ-

Photo: Eduardo Oliveira, WSL

ed in the large-scale modelling of land use, which is so important, for example, for improving worldwide climate models. The researchers will then test the model extensively in three case studies: In the Zurich region, where the political and planning context is similar to that in the 21 regions studied; in a post-communist context, namely, the urban region of Bucharest; and in a US-American context in Austin (Texas). These last two case studies should give clues about the extent to which the model, and specifically the operationalization of strategic spatial planning, can be applied worldwide.

Politics and the administration – or investors

The results of the research project to date indicate, for example, that strategic spatial planning in urban regions is approached differently: In northern and central European cultures, politics and the administration generally develop overall guidelines for a large region together with private actors. In Anglo-Saxon countries, however, it is the investors who have considerable negotiating power in implementing, for example, new housing projects. Where large strategic urban projects, such as a new harbour city or a new housing area, are setting the course of development, new questions arise: How compatible are such projects with the implementation of the overall guidelines? And are large regions with several smaller centres really better suited for sustainable landscape development than mega-centres such as London, Madrid or Paris?

With the basic knowledge arising from the research project about the effects of strategic spatial planning in urban regions, large-scale land-use models can be improved. They can then provide a useful basis for deciding on planning. *(rlä)*

Strategic development zone in Dublin's harbour city, marked with a red border.

Photo: Dublin City Council

BIODIVERSITY

How farmers can be encouraged to use nature conservation measures voluntarily

Tree groups in the midst of arable land can help protect soil, water and biodiversity.

Researchers at WSL asked farmers what motivated them to plant trees on their land, for example, to help protect biodiversity, water or soil. The survey is part of the international project BASIL (Balancing Agroecosystem Services In Landscapes), which is investigating what agricultural and environmental policy measures can promote sustainable agriculture.

The initial results of the survey of around 200 farmers in Germany, Spain and Switzerland indicate that: Money does increase their willingness to plant trees, but the respondents in all three countries tend to view additional nature conservation programs critically. The farmers were most likely to plant trees to protect their own soil and less readily for the sake of biodiversity, at least in Spain and Switzerland. If colleagues, however, recommended planting trees, the respondents were more willing to implement the same measure. Scientific recommendations were mostly poorly received, and in Switzerland tended to be even counterproductive.

If voluntary nature conservation in arable land is to be promoted, then care should be taken to emphasise the added value for farmers. In addition, it is worth trying to motivate them to exchange among themselves and to learn from each other. In order for research to receive more attention from practising farmers, recommendations should be embedded within more comprehensive consulting activities. *(chu)*

www.wsl.ch/basil-en

Photo: Thomas Waltert, WSL

BIODIVERSITY

Professional journal, Internet or discussion: How professionals in nature conservation keep informed

Environmental research is continually producing new findings. These are often relevant for professional nature conservationists, among other people. To see how they obtain this information, WSL carried out an online survey to which more than 350 professionals from all areas of nature conservation across Switzerland responded. The conclusion was that these conservationists use many different sources of information in their work. For most of them, their own experience or discussions with colleagues and experts are more important than reading articles in professional journals and fact sheets from research. This means that researchers should spend more time discussing their work directly with professionals in nature conservation. The report on the survey is available in German as a PDF on WSL's website. *(lbo)*

www.wsl.ch/berichte

BIODIVERSITY

Microcosm in the fork of a branch

A tree cavity is much more than just a hollow in a branch fork or tree stem: It is its own small cosmos, periodically filled with water, which is inhabited by leaf-decomposers like insect larvae, worms and microorganisms. Birds, small mammals and insects hunt them and use the cavities as a water source. The WSL entomologist, Martin Gossner, has been investigating these small ecosystems as they are good indicators of environmental changes. Studies in Germany, for example, have shown that intensive forest management reduces the species diversity in the cavities as fewer habitats and less food is available. To obtain standardised information, Martin and his team created artificial tree cavities using plastic buckets securely attached to the tree stems. Their initial results indicate that this model system allows them to test how changes in the spatial distribution, variety and condition of the cavities affect the species communities and the processes associated with them, such as the decomposition of plant material. *(bki)*

Trees cavities filled with water are small ecosystems that respond quickly to changes in the environment.

Photo: Martin Gossner, WSL

BIODIVERSITY

Mercury in the soil: How bacteria and fungi cope with the contamination

Between 1930 and 1970, the chemical plant Lonza in Visp (Canton Valais) released mercury into the Grossgrund Canal via its waste water. Some of the poisonous metal accumulated in the sediment, but was not for a long time identified as a problem. Up until the 1990s, the Canton and Municipality merely dredged the Canal periodically to keep it flowing. The excavated material was used as fertilizer or filling material for the nearby fields and gardens. It was not until 2010, during preparatory work for the construction of the A9 motorway, that the soil contamination was, by chance, discovered.

Adapt and remove

Nobody has, up until now, investigated how long-term mercury contamination affects soil organisms. The microbiologist Aline Frossard and her colleagues therefore analysed soil samples from around the Grossgrund Canal. The activity and growth rates of the microorganisms in the contaminated soil were more-or-less the same as those in the uncontaminated soil – which indicates that the mercury probably did not influence the soil quality. The species diversity of the microorganisms also did not differ. What did, however, change was the composition of the bacterial and fungal communities.

These results came as no surprise to Aline: "For one thing, microorganisms adapt quickly to changes in environmental conditions. If one species, for example, disappears because the level of mercury is too high, another will take over its place and function. Moreover, microorganisms in the soil can transform toxic mercury into a non-poisonous form and thus adapt to the inhospitable conditions." In a further experiment Aline was able to show that the soil texture influenced how the mercury affected the soil organisms. The amount of biologically available mercury was, for example, less high in limy soils than in other soils.

The contamination of the Grossgrund Canal and nearby soils had, apparently, no effect on human health, as a University of Zurich study already found in 2016. The contaminated soil is now being gradually removed and cleaned up. When peace and quiet finally return to the region, the locals will be happy. *(lbo)*

Benjamin Fischler, Davos

“After work I often get on my bike and ride from Klosters up to Casanna Alp. The incline is comfortable, although there’s a tough stretch just below the Alp. But each drop of sweat is worth it: The view across Prättigau to the Silvretta Glacier is fantastic!”

TINKERING FOR SCIENCE

Benjamin Fischler is a multi-skilled mechanic and vocational trainer, who produces all kinds of technical devices to help researchers at WSL. With the Instrumented Field Sites Team, for example, he built the shear apparatus for snow. Researchers use it to carry out load experiments to find out more about when and how cracks form in snow. “Working in the workshop or out in the field is great fun. I also really like training the apprentices and doing such varied work.”

Photo: Bruno Augsburger, Zurich

Avalanche protection policy for Iceland

These test installations above Siglufjörður were used to find out which types of structure are suitable for Icelandic conditions. The snow in the foreground is more than 8 metres deep.

Northern Iceland in winter: The raging storms bring large quantities of snow. The wind blows clear exposed ridges, but fills depressions and gullies with several metres of often wet snow. Large cornices form along the edges of the table mountains. Small fishing villages nestle directly at the foot of the massive steep slopes.

In 1995, 34 people lost their lives in avalanches in two of the villages, Súðavík and Flateyri. Unlike with earlier catastrophes, the Icelanders no longer considered it to be unavoidable, and in Reykjavik there were even demonstrations. The Icelandic government thereupon decided to have protection needs throughout the country analysed. The avalanche protection expert, Stefan Margreth from SLF, was involved in drawing up the report. "The result is a kind of master plan that indicates the necessary measures to be taken over the next 20–30 years," Stefan explains. Since then he has visited Iceland almost every year. After the master plan came the realisation of the protection projects. Here Stefan's expertise in planning supporting structures was particularly in demand as they were then new to Iceland. Stefan and his Icelandic colleagues used a test site above Siglufjörður to investigate whether the supporting structures that are best practice in the Alps also function in Iceland. They found that these structures are also suitable for Iceland, but unlike in Switzerland, much more attention must be paid to, for example, providing protec-

Photo: Sveinn Brynjólfsson, Icelandic Meteorological Office tion against corrosion in the salty air close to the sea.

Iceland is learning from Switzerland – and vice versa

Siglufjörður is now protected by a series of structures, whose total length amounts to more than four kilometres, as well as a large diversion dam and several catching dams. "Involving the locals early on and employing landscape architects helped to ensure these large constructions would be well accepted," Stefan Margreth concludes. "What was most exciting was that we could build up the whole protection system from scratch." This is rarely the case in the Alps today. "The resulting experience has been very valuable for checking our calculations and designs," says Stefan.

It's not only in Iceland, but also in seemingly more exotic countries like Chile, Russia or Iran that experts from SLF are advising and supporting those locally responsible in avalanche protection. Even though the challenges may be very different, SLF also always benefits from the new experiences. What is different about the work in Iceland? Stefan Margreth: "In Iceland, what you suggest and plan is really implemented, which is very satisfying!" This is certainly also satisfying for Siglufjörður's inhabitants, who can now sleep quietly through even the worst winter storms.

(bio)

NATURAL HAZARDS

Repairing the scales for debris flows

The Illgraben is unpredictable. In this mountain streambed above Leuk (Canton Valais), several debris flows, containing a destructive mixture of water, mud and rocks, thunder down into the valley each year. WSL has installed a series of measuring instruments here, including a set of scales, a so-called force plate, which was built into the streambed in 2003. The aim is to use the collected data to understand the dynamics and flow behaviour of the debris flows better. By the time the scales were ripped out of their foundations and completely destroyed on 22 July 2016, they had weighed over fifty debris flows, each with an average weight of about 46 000 tons. On that day, the culprits, three enormous boulders weighing between twenty and thirty tons, were swept down into the valley in a debris flow. Thanks to a major investment of WSL, the scales can now be restored and optimized during the winter of 2018/19. At the same time, other measuring instruments will also be upgraded. *(lbo)*

A debris flow swept away the three-ton set of scales in the Illgraben, depositing it in the Rhone river. In the photo you can see the large boulders that caused the destruction.

Photo: Brian McArdell, WSL

www.wsl.ch/illgraben-en

Snow in East Antarctica: How much turns to ice?

Even though the snow density data is recorded automatically, measurements by hand are still necessary – in often hostile conditions – to calibrate the instruments.

Climate change is causing glaciers worldwide to melt. Worldwide? Not in East Antarctica – an area larger than the whole of Australia – where ice stocks are growing. "There's more precipitation than there used to be. As it is still cold enough, it falls as snow, which turns into ice," explains Michael Lehning, who, at SLF and at EPFL, is investigating the interactions between the atmosphere and snow cover. It is open to question whether the increase in the East can compensate for the ice loss in the rest of Antarctica and the associated rise in sea levels. To check this, we need to know how much snow turns to ice and where. This is not particularly easy: Severe storms frequently shift the snow around, and some of it is sublimated back to the atmosphere. Michi wants to understand the processes involved.

This is why, in 2016, he went to the inland research station Princess Elisabeth, where he installed a new kind of sensor combination to automatically record the transport and deposition of snow. "The station is powered by solar and wind energy, and was able to provide data throughout the whole winter. This data is unique!" exclaims Michi delightedly. This year he has also been measuring the same parameters closer to the coast, where snow deposition may proceed differently. The data analyses will help to obtain a more precise mass balance of the Antarctic ice. *(bio)*

www.slf.ch/massbalance-antarctic

Photo: Nander Wever, SLF

Water is accelerating rock glacier creep

Robert Kenner is an enthusiastic permafrost researcher. For the past eight years at SLF, his focus has been on the permanently frozen ground in the Swiss Alps – for example, in the Ritigraben near Grächen (Canton Valais). There, over the past thousands of years, a rock glacier has formed, consisting of a mixture of debris and ice.

Rock glaciers creep slowly down towards the valley. In recent decades, however, they have been moving faster due to climate change. This increases the risk of natural hazard events. Robert explains: "The faster a rock glacier creeps, the more likely rockfall and debris flows become."

Seasonal patterns

Using measurements in boreholes, as well as laser scans, aerial photography and GPS, Robert found that the rock glacier in the Ritigraben is moving mainly in a layer about 20 metres deep, the so-called shear horizon. The rock glacier is now creeping four times faster than in the year 2000, and its movements have a distinctly seasonal pattern. It reaches the highest velocities between August and November, before slowing down in winter up until the beginning of the snow-melt, when it quickly accelerates again. Moreover, after heavy rainfall, the rock glacier may, for a short period, move 16 times faster than normal.

Water seems to play an important role in influencing the creeping velocity. Robert: "We assume that rain and melt-water can penetrate the rock glacier more easily today than previously because the ice has become warmer with climate change." This leads to less friction in the shear horizon and thus an increase in the creep velocity. Some rock glaciers are depositing more debris in steep channels – and thus further increasing the risk of rockfall and debris flows. *(chu)*

Laser scanning on the Ritigraben rock glacier.

Photo: Marcia Phillips, SLF

Johanna Donhauser, Birmensdorf

"Last summer I discovered the Lindenhof midst in the city of Zurich. Since then I've been coming here regularly with my guitar to make music with friends. We play mostly songs from the 1960s and 1970s in singer-songwriter style, and enjoy the liveliness of the place."

ARCTIC SOIL UNDER CLIMATE CHANGE

What happens if you warm soil from cold regions? Does the diversity of fungi, bacteria and other microorganisms increase or decrease? How do the carbon and nutrient cycles change? The doctoral student Johanna Donhauser is carrying out experiments in the Swiss National Park in Canton Grisons and in the Arctic as part of the international MicroArctic Project to study the influence of climate change on soils.

Photo: Bruno Augsburger, Zurich

OUTLOOK, DIAGONAL NO. 2, 2018

Everything is interconnected – and not only since the Internet has been around. In nature, this principle has always applied: Stream courses, hedges and 'green' bridges connect habitats; animals eat plants or other animals and thus mutually influence each others' populations; and fungal networks help forest trees to take up nutrients more easily. Researchers at WSL don't just study how natural networks function and how they can be restored after an intervention. They themselves also benefit from a diverse variety of networks, with networks of computers, of instruments and of researchers making their work easier.

Photos: Beat Wermelinger; Thomas Reich, WSL

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Request individual copies:
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IMPRINT

Publisher:
Prof. Dr. Konrad Steffen, WSL Director

Text:
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Translation: Silvia Dingwall, Nussbaumen

Design:
Raffinerie AG für Gestaltung, Zurich
Layout: Sandra Gurzeler, WSL

Printing:: cube media AG, Zürich

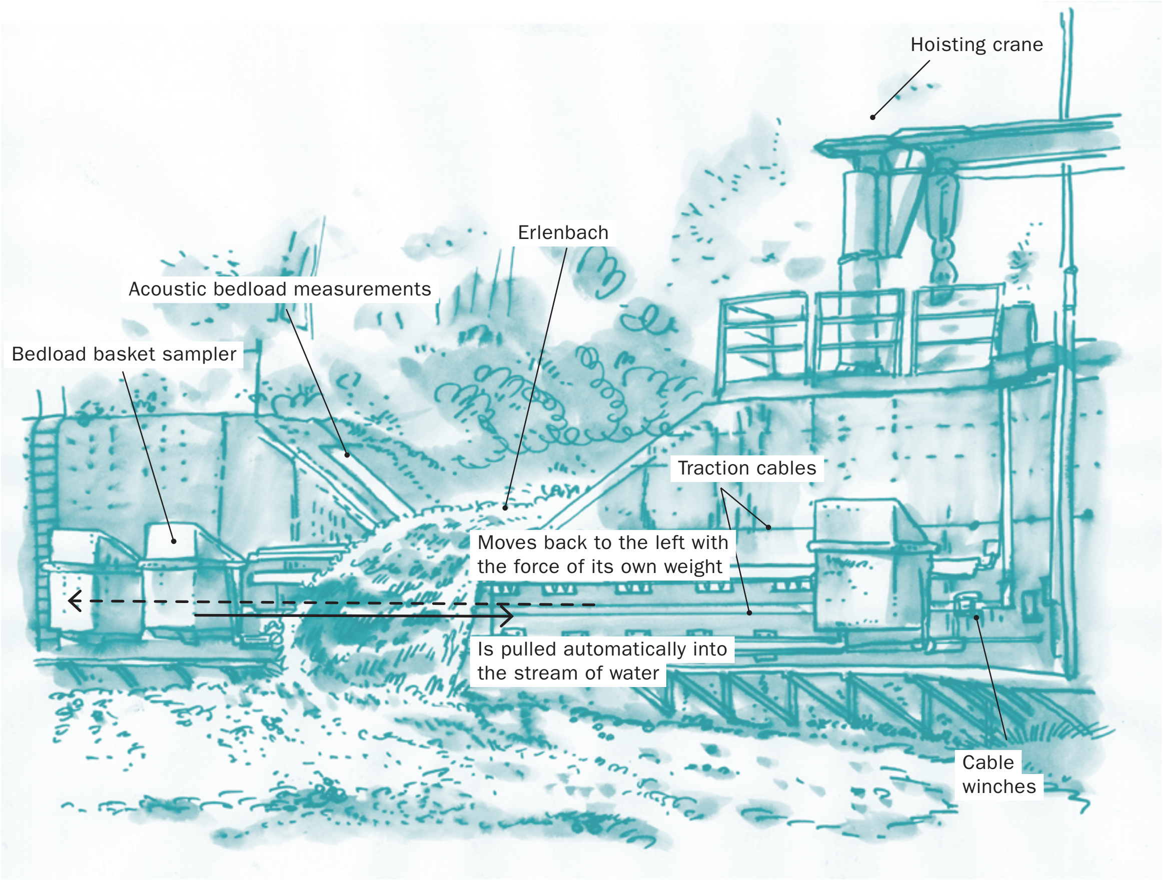
Circulation and frequency of publication: 1900, twice annually

The WSL magazine DIAGONAL is also published in German and French.

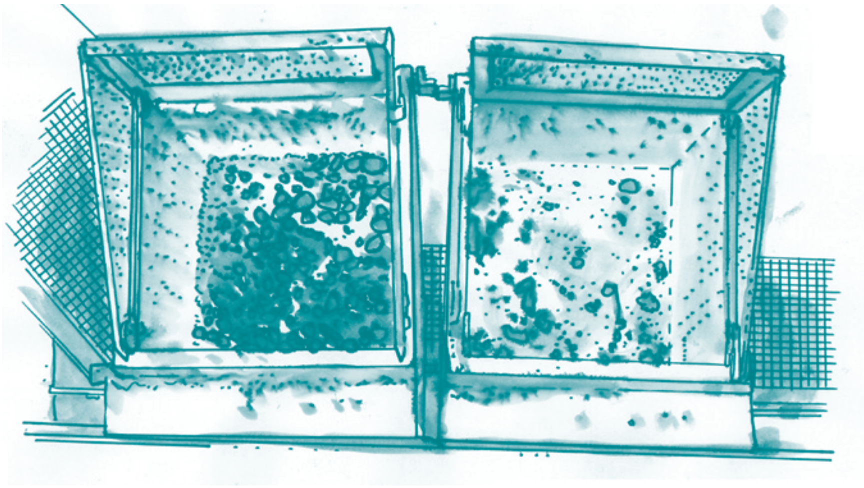
Cite as:
Swiss Federal Research Institute WSL, 2016: WSL magazine Diagonal, 1 / 18. 36 pp., ISSN 2296-3561

PEOPLE

The WSL editorial team, from left to right, top row: Sandra Gurzeler, Claudia Hoffmann, Lisa Bose; middle row: Birgit Ottmer, Beate Kittl, Christine Huovinen; bottom row: Reinhard Lässig, Sara Niedermann



View inside the basket



Floods in torrents frequently transport large quantities of stones and sand down with them. In the Alptal (Canton Schwyz), WSL has been measuring how much material the Erlenbach transports. When a flood event occurs, metal baskets move automatically into the stream and collect the solid material. Along with the data from the acoustic sensors, the researchers can then determine the bedload transport for different particle sizes.

Video at:
www.wsl.ch/object

Avalanche protection: Iceland learns from Switzerland – and vice versa, p. 30

Tree cavities: Plastic buckets simulate microcosms, p. 27

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RESEARCH FOR PEOPLE AND THE ENVIRONMENT

The Swiss Federal Institute for Forest, Snow and Landscape Research WSL conducts research into changes in the terrestrial environment as well as the use and protection of natural spaces and cultural landscapes. It monitors the condition and development of the forests, landscapes, biodiversity, natural hazards, and snow and ice, and develops sustainable solutions for problems that are relevant to society – together with its partners from science and society. WSL plays a leading international role in these research areas, providing the basis for sustainable environmental policy in Switzerland. WSL employs more than 500 people in Birmensdorf, Cadenazzo, Lausanne, Sion and Davos (WSL Institute for Snow and Avalanche Research SLF). It is a Swiss federal research center and part of the ETH Domain. You can find WSL's annual report online at: www.wsl.ch/more/annualreport.

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