AVALANCHE RESEARCH

Computer Models Aim to Keep Ahead of Snowslides

This year's severe avalanche season in the Alps was a test for Switzerland's avalanche forecasters, but the data should improve future predictions

DAVOS, SWITZERLAND—For Swiss avalanche researcher Perry Bartelt, work came uncomfortably close to home one Saturday morning in February when he was making breakfast. Suddenly, across the valley, a wall of snow slid down the Brämabüel mountainside, snapping tree trunks, burying the main road under 10 meters of snow, and then, to his surprise, surging up the steep incline toward his neighborhood. The avalanche stopped 50 meters short of the lowest chalet, but cut off the access road for several days.

"I never expected that," says Bartelt, the head of avalanche dynamics and numerical modeling for Switzerland's Federal Institute of Snow and Avalanche Research (SLF). He and his colleagues had used a computer model to simulate how snow might slip down that slope, and it had predicted a smaller avalanche. "Our dynamics model was pretty much on target, but we had underestimated the volume of snow. Now we need to reassess our assumptions on 'fracture depths' "—the point at which the snow slab breaks to start the avalanche. Instead of fracturing at the typical depth of 1 to 1.5 meters, the Brämabüel avalanche began as a 3-meter-deep slab of snow that picked up more mass as it hurtled into the valley.

For Bartelt and his team of half a dozen snow and avalanche modelers at the Davos institute, this winter's severe Alpine avalanche season—with more than a thousand avalanches and 31 fatalities in Switzerland alone—is a watershed. Although SLF's researchers have made great strides in understanding avalanches in the 63 years since it was founded, this year's season—the worst since 1951—revealed some key weak points in their numerical models. No one claims to be able to predict that an avalanche will occur at a particular spot at a specific time, but the researchers want to give better assessments of the threat and more accurately estimate runout distances so local authorities can clear hazard areas.

Before this winter, the Davos researchers had already been refining their techniques, for example, by developing computer models that, based on data on recent snowfalls and weather, can predict how likely the snowpack is to fracture and slide.

Too close for comfort. SLF avalanche forecaster Perry Bartelt inspects the debris of the Brämabüel.

CREDITS: R. KOENIG

They are also supplementing models of avalanche dynamics that essentially treat the moving snow as a continuous fluid with more sophisticated "granular flow" models, which take into account the properties of the fast-moving granules in a flowing avalanche. The researchers hope that the wealth of data gleaned from this year's avalanches will accelerate that effort. "1999 should prove to be a breakthrough for avalanche modeling," says geographer Urs Gruber.

Nearly 50 years ago, in the severe winter of 1950–51, a tragic series of avalanches in the Alps spurred Swiss researchers to begin work in earnest to study the problem. A Swiss pioneer in the field, Adolf Voellmy, published the first treatise on avalanche dynamics in 1955, using a relatively simple model to calculate runout distance and maximum flow velocities. An improved Voellmy model is still widely used to prepare avalanche-hazard maps, but avalanche models became more sophisticated in the following decades, and the effort broadened to include researchers in France, the United States, Norway, Japan, and Iceland. Most in this field acknowledge the preeminent position of the SLF, however. Robert L. Brown of Montana State University in Bozeman, one of the foremost U.S. avalanche researchers, calls it "the premiere research institute in the world when it comes to snow and avalanches."

Avalanches usually occur within a few days of heavy snowfalls, when snowpacks fracture at unstable points—such as "depth hoar," a buried layer of large, weakly bonded crystals—underneath fresh snow. They can be big or small, fast or slow, depending on the amount and wetness of the snow, the topography, and meteorological conditions.

To predict when and how the snowpack is likely to fracture, researchers need to be able to model the mechanical strength of the snow. But that depends on a complex array of factors, such as the size and shape of the snowflakes in each snowfall, the strength of the wind that redistributes the snow, the temperature at the time of snowfall, and the pressures exerted by new snowfalls that compact the older snow beneath. One lesson from this winter's avalanche season, for example, is that some older layers of snow—which tend to be more compact and stable—should be taken into account in estimating likely fracture heights and runout distances. Existing guidelines are based on the belief that only 3 days' worth of snowfalls should be factored into such calculations, but the almost continuous heavy Alpine snow in February greatly increased the expected volume of snow in that month's avalanches.

To cope with all these factors, Bartelt and his team are now putting the finishing touches to an innovative simulation, called SNOWPACK, which models snow as a three-phase (ice, water, and air), porous, phase-changing medium. It takes into account the microstructural properties of snow (such as the size and shape of grains of snow, as well as their bonding strength), and traces the way the snow is transformed under changing pressure and temperature.

Atmospheric and environmental scientist Michael Lehning says the aim of SNOWPACK is to provide more details about the snow base so that avalanche forecasters can make more accurate predictions. The model is fed with meteorological data—including snowfall, temperature, wind speed, humidity, and solar radiation—that is sent hourly from the dozens of automatic measuring stations across the Swiss Alps. Lehning then uses that data to predict snowpack conditions through much of the Swiss Alps, including the rate at which the snow is densifying, the state of stress, and the microstructures of snow layers—all of which are used to determine the stability of the snowpack. Lehning is also developing a new model that seeks to predict the influence of wind on snow deposits—a significant factor in avalanches because it affects the accumulation and characteristics of the snow.

Meanwhile, SLF is refining its ability to predict what happens once an avalanche is unleashed—how fast and far it will travel. In the past, models of avalanche dynamics have treated the snow as if it were a flow of shallow water down a steep slope. But such equations only offer a simple, if well calibrated, description of avalanche motion, because an avalanche is actually a complex granular flow. So Bartelt says his researchers are now trying to make avalanche models more realistic by using complex granular-flow simulation. Such models track the motion of individual "particles"—clumps of ice formed during the avalanche's downward motion. Granular flow models require so much computer power that it is not yet feasible to use them for practical avalanche prediction and warnings. But Bartelt says "we are using granular-flow models to make the existing hydrodynamic flow laws more rational."

The SLF recently asked the Swiss National Science Foundation to help fund a major new effort to develop state-of-the-art particle models of snow entrainment (how the avalanche picks up greater mass as it descends) and sliding friction in dense snow avalanches. Researchers also want to apply these techniques to model how snow flows around avalanche defense structures, including earthen banks built up to protect towns.

Besides modeling avalanches and studying their aftermath in the field, the SLF researchers also test their models with experimental avalanches. On a cordoned-off mountainside near Sion, scientists—positioning themselves in a small bunker near the end of the runout zone—set off real avalanches using dynamite charges and then use radar to measure the flow velocities and other equipment to measure the pressure the snow exerts on various structures placed in its path. When the next big avalanche season comes, the SLF researchers plan to be ready for it.

–ROBERT KOENIG

ECOLOGY

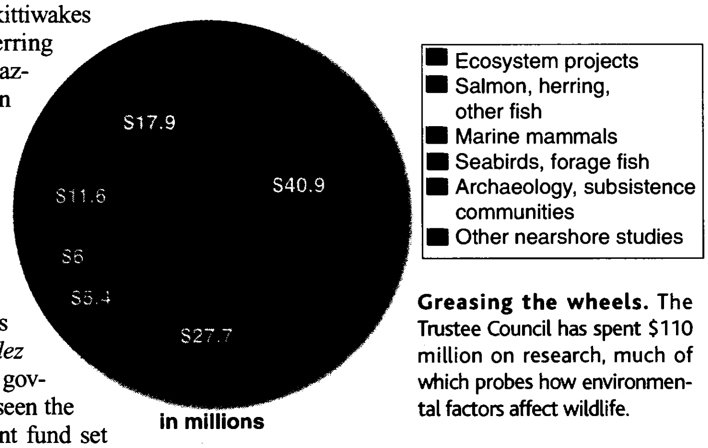
The *Exxon Valdez*'s Scientific Gold Rush

Ten years after the worst oil spill in U.S. waters, scientists are learning valuable lessons from the research done in the disaster's wake

ANCHORAGE, ALASKA—To study how seabirds forage, David Duffy used to have to chase after a flock in a skiff or bargain his way onto an oceanography ship to steal a few moments of observation time. No longer. Four years ago, the University of Alaska, Anchorage, ecologist found himself aboard whalers racing up to 60 kilometers an hour after radio-tagged kittiwakes and tracking schools of herring by sea and by air. "The amazing thing is, we were given enough resources" to mount the ambitious, expensive studies, says Duffy, now at the University of Hawaii, Honolulu. "It's like being let loose in the toy store."

Duffy's spree comes courtesy of the *Exxon Valdez* Oil Spill Trustee Council, a government body that has overseen the $900 million civil settlement fund set up after the infamous supertanker ran aground on 24 March 1989, disgorging 42 million liters of crude oil into pristine Prince William Sound. The fund was established to restore and conserve the sound's natural resources, but researchers like Duffy have snared a big chunk—$110 million over the past 8 years—to probe how the region's ecosystems have recovered from the spill. Their work is beginning to unravel how relationships spanning the food web—from the lowliest plankton to killer whales—and shifts in ocean temperatures have driven alarming species declines in the Gulf of Alaska, which supports some of the richest fisheries in the United States.

Scientists gathered at a symposium* here last month, 10 years after the worst oil spill in U.S. waters, to trot out findings from what may be the most expensive ecology program ever. After a rocky start afflicted by subpar studies done on the fly in the initial months after the spill, many researchers say the fund has transformed *Exxon Valdez* science from a scientific pariah to a respected effort. Marine ecologist Charles Peterson of the University of North Carolina, Chapel Hill, who's helped guide the program as a reviewer, calls the recent work "just magnificent."



Greasing the wheels. The Trustee Council has spent $110 million on research, much of which probes how environmental factors affect wildlife.

SOURCE: *EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL

But like most aspects of the *Exxon Valdez* disaster, the research program has sparked controversy. Some observers question its underlying philosophy, which is to restore resources by understanding them better. "We can't fix what was broken here. The notion that studying it was helping it is perverse," says University of Alaska, Anchorage, outreach adviser Richard Steiner, a longtime critic of the council-funded science. And some prominent ecologists question the vast expenditure on studying the fallout of a local calamity when research efforts on more-imperiled species and global problems like tropical deforestation are scrambling for funds. "I still have some big problems with this way of doing science, the philosophy of requiring a catastrophe of this sort to generate this effort to understand nature," says Jim Estes of the U.S. Geological Survey in Santa Cruz, California.

The research bonanza is now drying up, as the fund shifts its focus from restoration to long-term monitoring. As scientists debate the program's value, they acknowledge they may never see its like again: The law that brought the Trustee Council to life has been revised to encourage faster restoration efforts and fewer field studies in the wake of future environmental debacles.

Into the breach. Scientists were caught off guard in the hours after the tragic spill. Few data existed on the sound's ecology, so some, in desperation, scrambled out on the water to snap Polaroid photos of the shoreline before the oil started washing up. "It was a crisis atmosphere," says Stan Senner, science coordinator for the Trustee Council. The panic-driven initial studies often featured inadequate controls and ignored possible explanations other than oil for wildlife declines;

* Legacy of an Oil Spill—10 Years After *Exxon Valdez*, 23–26 March, Anchorage, Alaska.