Q&A: Researcher discusses predicting the landslide in Brienz

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This rock avalanche almost reached the village of Brienz. Credit: Keystone-SDA

The landslide in Brienz (GR) in 2023 kept Switzerland on tenterhooks for weeks. Researchers from ETH Zurich, WSL and SLF used a model to provide a highly accurate blind prediction of where the sliding mass would come to rest.

Gaume, joint professor of alpine mass movements at ETH and SLF, studies avalanches, landslides, granular and debris flows. He and his team have developed new simulation software to estimate which areas could be at risk from natural disasters such as these. Just before the landslide took place in Brienz, they were able to predict how far the rock avalanche could travel—and the actual event ultimately provided "empirical" evidence of the simulation's accuracy. In this interview, the researcher explains how his model works and why he was reluctant to communicate his findings last summer when the landslide was in the news.

With the aid of your new model, you were able to predict in advance virtually down to a meter's accuracy where the debris from the Brienz landslide would come to rest. What is the secret behind this model?

Previous models were two-dimensional and drawn up in accordance with empirical friction laws whose parameters were usually back-calculated based on data from past events. Since real events don't take place very often under similar conditions, calibration is not easy, which results in major modeling uncertainties. Our model, in contrast, is based on the materials involved, i.e., ice, snow and rock; is entirely three-dimensional and essentially requires only three components: a digital elevation model to represent the topography, the volume of materials released and various mechanical properties such as friction and the rigidity of the landslide mass. We can evaluate these factors using classic geotechnical laboratory tests.

Was the model developed specifically for the case of Brienz?

No. It was originally developed to simulate snow avalanches. However, since our code is material-based, it is relatively easy to add a different material model and simulate the behavior of rock, ice and water.

Why was Brienz so important to you?

Brienz was an opportunity for us to make a contribution and test how accurately our model predicts such events. Until recently, we had only been able to test our model against past events. This was what made Brienz of particular interest to us. Given the high probability of an occurrence of a major event like this, we used our simulations to make a blind forecast and presented our results to the cantonal authorities.

What was the forecast?

We created two scenarios: a dry one and a pessimistic one involving a lot of water, which increases the mobility of the rock material. In the case of a dry landslide, we predicted that the landslide would stop around 20 meters short of the village. However, our second scenario indicated that the rockslide could impact more than half of the village if a lot of water was involved.

That sounds like a highly accurate prediction for a dry scenario. How realistic is your model?

Although we were pleased to find that our simulation was well borne out by reality, our modeling results were not perfect and included some discrepancies. For example, the material volume in our simulation was slightly overestimated. In addition, our model featured more lateral spreading than what we observed in reality.

Why did you hold back with your predictions last summer?

While I was happy about the accuracy of the simulation that we had been working on for years and I wanted to rapidly communicate this in the case of Brienz, there were a number of major uncertainties—such as the question of water and the release scenario. If there had been a lot of water involved, the simulation would have been highly inaccurate, because it fails to fully model hydro-mechanical couplings. This is something we are currently working on. =

But we were also reluctant to communicate our prediction given the sensitivity of the political aspect. People at the location could have misunderstood such a message. If my model predicts that a major event will occur and will come to a halt 20 meters from my house, I will obviously evacuate in the face of too many uncertainties.

How long have you been working on this model?

Since 2017. This is when I started working with my colleagues from SLF and the University of California, Los Angeles (UCLA) on a new generation of computer models that simulate alpine mass movements as accurately as possible. These not only include snow, ice, rock and debris flows but also cascades—a process where, for instance, a rock-ice avalanche triggers a debris flow. On balance, I have spent years working on the modeling aspects related to the triggering and dynamics of mass movements in the Alps.

How can you improve the model?

A postdoctoral researcher in my group at ETH/SLF is currently re-analyzing the Brienz data, and we will run additional simulations to evaluate our predictions and find out what we could have done better. We will present our blind simulations and subsequent analyses at the INTERPRAEVENT 2024 Conference in Vienna this summer.

We are also developing other models in which we can combine solids and liquids at the same time in order to get a mixture of a viscous liquid and coarser larger particles such as boulders. We are also extending our models to better analyze the effects of global warming. To do this, we need models that not only simulate the interaction between the liquid and solid phases but also capture phase changes from solid to liquid or temperature effects.

We are also working on simulating process cascades, such as those that occurred on Piz Cengalo above Bondo. In the case of such cascades, one event triggers another, which goes on to trigger another. Such catastrophic process cascades could become more frequent and intense as a result of climate change. They start high up in the alpine zone and can flow down into the valley as a mixture of liquid and solid components.

Do you make your models available to practitioners?

In order to make the models available to practitioners, we first need to make them easier to use. We will soon start working on the development of a graphical user interface to make them more user-friendly. We also want to improve the efficiency of our code. The Brienz simulation, for example, had a resolution of two meters and used about two million particles. It took less than ten minutes to run on a good office computer. A version that can use graphics processors and AI tools would allow us either to improve the resolution or to have simulation results available in less than a minute.

How will you use the model in the future?

We are using our model for both research and consultancy purposes at present. We have had requests from the cantonal authorities and engineering companies to perform simulations in cases where classic approaches are difficult. However, most of our work currently relates to research. Given the improvements and developments we plan for our model, I suspect that it could also be of interest to practitioners.

What other cases in Switzerland or in the Alps might you apply your model to in the near future?

We are currently involved in an important WSL project called Climate Change Impacts on Mass Movements (CCAMM), where we are carrying out scenarios and simulations in the Kandersteg area at Spitze Stei above Lake Oeschinen, where the rock slope is considered to be unstable. We are simulating a potentially massive rock avalanche that could reach the lake and trigger a tsunami. This could carry saturated sediments and cause a debris flow that might endanger the village of Kandersteg.

More information: A. Cicoira et al, Towards a predictive multi-phase model for alpine mass movements and process cascades, *Engineering Geology* (2022). DOI: 10.1016/j.enggeo.2022.106866

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