A glacier's life

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EPFL researchers have developed a numerical model that can re-create the state of Switzerland's Rhône Glacier as it was in 1874 and predict its evolution until the year 2100. This is the longest period of time ever modeled in the life of a glacier, involving complex data analysis and mathematical techniques.

The work will serve as a benchmark study for those interested in the state of glaciers and their relation to climate change.

The Laboratory of Hydraulics, Hydrology and Glaciology at ETH Zurich has been a repository for temperature, rainfall and flow data on the Rhône Glacier since the 1800s. Researchers there have used this data to reconstruct the glacier's mass balance, i.e. the difference between the amount of ice it accumulates over the winter and the amount that melts during the summer(see 1 below). Now, led by professor Jacques Rappaz from EPFL's Numerical Analysis and Simulations group, a team of mathematicians has taken the next step, using all this information to create a numerical model of glacier evolution, which they have used to simulate the history and predict the future of Switzerland's enormous Rhone glacier over a 226-year period.

The mathematicians developed their model using three possible future climate scenarios. "We took the most moderate one, avoiding extremely optimistic or pessimistic scenarios," explains PhD student Guillaume Jouvet. With a temperature increase of 3.6 degrees Celsius and a decrease in rainfall of 6% over a century, the glacier's "equilibrium line", or the transition from the snowfall accumulation zone to the melting

zone (currently situated at an altitude of around 3000 meters), rose significantly. According to this same scenario, the simulation anticipates a loss of 50% of the volume by 2060 and forecasts the complete disapearance of the Rhône glacier around 2100.

"It is the first time that the evolution of a glacier has been numerically simulated over such a long period of time, taking into account very complex data," notes EPFL mathematician Marco Picasso. Even though measurements have been taken for quite some time, the sophisticated numerical techniques that were needed to analyze them have only been developed very recently.

To verify their results, the mathematicians have also reconstructed a long-vanished glacier in Eastern Switzerland. They were able to pinpoint the 10,000-year-old equilibrium line from vestiges of moraines that still exist (see 2 below).

The scientists' work will be of interest not only to climate change experts, but also to those to whom glaciers are important – from tourism professionals to hydroelectric energy suppliers. Picasso adds that this numerical model could be applied to the polar icecaps. "Mathematics and numerical methods have an important role to play in our society," he enthuses. "They allow us to simulate with great confidence a large number of environmental phenomena."

This research, conducted by the team in Zurich was published in 2008 in the *Journal of Geophysical Research*.

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