

Open Bachelor- and Master Theses at VAW/Glaciology

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Modelling the trajectory of a crashed aircraft on Gauligletscher (*Master thesis*)

On 19 November 1946 the crew of a military aircraft became disoriented in bad weather conditions, and the aircraft crash-landed on the uppermost part of the Gauligletscher (Bernese Alps) at an altitude of 3,350 meters a.s.l. The crew could be rescued, but the aircraft was left there and has been submerged by subsequent snow accumulation and it never re-emerged up to now.

Goal: Reconstruct the trajectory along which the aircraft has been transported by the ice flows, which has to be computed with a three-dimensional glacier flow model. By integrating the transient ice velocity field forward in time, starting from the location where the plane disappeared at the glacier surface in 1946, the most likely point and time of emergence on the glacier can be determined.

All necessary data and models are available. However, some data processing is necessary prior to the modeling work (Dr. Guillaume Jouvet).

Comparative study of ice flow models of different complexities (*Master thesis*)

The dynamics of glacier ice is commonly modeled by non-linear Stokes equations combined with Glen's flow law. However, those equations are usually too computationally demanding to be used in many practical applications (like e.g. in ice sheet modelling). For this reason, several simplified "shallow" models have been developed to run large scale simulations.

Goal: i) Understand the equations of the ice mechanics, and to derive two basic simplified models by a dimensional analysis: the Shallow Ice Approximation (SIA) and the Shallow Shelf Approximation (SSA) ii) Formulate a suitable numerical model iii) Implement SIA and SSA with Matlab in a flow-line setting iv) Perform some comparison tests with a set of benchmark modelling exercises in order to assess the mechanical and computational performances of each model. A follow-up of this work would be the implementation of recent model which combines SIA and SSA by a multilayer approach (Dr. Guillaume Jouvet).

Intercomparison between models estimating glacier ice thickness (*Bachelor thesis*)

Knowledge about the ice thickness distribution of a glacier is a fundamental pre-requisite for a number of glaciological applications. On a global scale, however, this knowledge is remarkably limited, since measuring glacier ice thickness directly is laborious and expensive. To overcome the problem, a series of methods that infer the ice thickness distribution of a glacier from characteristics of the surface have been developed. To date, however, such methods have not been compared against each other, leaving the question about their relative performance unanswered.

Goal: Support the model intercomparison experiment that will be called by the International Association of Cryospheric Sciences (IACS), by applying a set of existing models to a series of test cases. The test cases include glaciers from different regions around the globe and have previously been defined. The work will be carried out in close collaboration with the Swiss Federal Institute for Forest, Snow and Landscape Research WSL (Dr. D. Farinotti).

Global scale glacier modeling: intercomparison of different approaches (Master thesis)

The anticipated retreat of glaciers around the globe will pose far-reaching challenges to the management of fresh water resources and will raise sea level significantly within only a few decades. Current global glacier models depend on strongly simplified and often empirical descriptions of the driving processes hampering the reliability of the results. Recently, a novel process-based model for calculating the response of surface mass balance and three-dimensional geometry for each individual glacier around the globe was developed at ETH Zürich. Thus, the response of each of the world's roughly 200,000 glaciers outside of the two ice sheets Greenland and Antarctic to 21st century climate change can be calculated. The uncertainties are still high, however, and it is yet unclear which processes are most relevant to increase the confidence in the results.

Goal: Run a global glacier model for the period 1980 to 2100 and investigate the impact of different approaches to calculate surface accumulation, snow- and icemelt, glacier retreat and calving of marine-terminating glacier on the final results. In particular, the skill of different model approaches to reproduce observational data sets will be studied. This work involves computer modeling and the treatment of large amounts of data (Dr. D. Farinotti).

Seismic monitoring of bedload transport at Erlenbach, SZ and Gornera, VS (2 Master's thesis)

Quantitative monitoring of bedload transport in rivers and torrents is difficult but essential in geomorphologic studies. An innovative and promising approach captures acoustic and seismic signals emitted during the impact of mobilized particles with the streambed. Thus, geophone installations directly in streambeds have provided new constraints on bedload transport events. At the same time, the data from seismometers installed at some distance from a channel are more difficult to interpret. One key challenge is to separate the seismic bedload signal from the water turbulence signal. Therefore, in contrast to in situ geophone time series, which can be analyzed with simple count-thresholds, the frequency signature has to be considered when seismic data are acquired remotely. Theoretical spectra of bedload transport and water turbulence have been proposed, but comprehensive data sets are needed in order to test and apply these concepts to real river seismograms.

Goal: Characterize the frequency spectra of river seismograms in the presence and absence of bedload transport. The study will use seismic measurements near the Gornera, VS, and Erlenbach, SZ, where bedload transport can also be measured with alternative and state-of-the-art techniques. As a supplement, seismic data near melt streams on the surface of Gornergletscher (catchment of Gornera) can be used to measure purely non-erosion seismograms. These studies can include fieldwork and will be conducted in collaboration with the Swiss Federal Institute for Forest, Snow and Landscape Research WSL (Prof. Fabian Walter, Dr. Dieter Rickenmann and Dr. Alexandre Badoux).

Remote methods for debris flow early warning at Illgraben, VS (Master's thesis)

Debris flows are a serious natural hazard in Alpine terrain. These events form as eroded material slides into torrents and mobilize a mixture of water and entrained debris of various grain sizes. The Swiss Federal Institute for Forest, Snow and Landscape Research WSL maintains a debris flow monitoring site at the Illgraben, VS, including check dams, geophone and force plate sensors and laser altimeters to measure the depth profiles of debris flow events. A recently installed seismometer network furthermore showed that slope erosion processes and debris flows generate a seismic signal and can thus be detected remotely and in some cases be located.

Goal: Combine data from a seismometer test installation and an infrasound antenna to test if either or both signals are suitable for early warning systems of debris flow events. The work will be conducted in collaboration with the Swiss Federal Institute for Forest, Snow and Landscape Research WSL (Prof. Fabian Walter and Dr. Brian McArdell).

Numerical modelling of Transbaikalian mountain glaciations in Siberia (Master's thesis)

The Kodar Mountains (57°N, 118°E) and adjacent ranges located east of Lake Baikal currently host only small cirque glaciers confined to their highest parts. Although the region currently experiences a cold continental climate with little winter precipitation, this has likely not always been the case. Indeed, massive moraine complexes and an expansive network of U-shaped valleys indicate that the region has previously hosted much larger glaciers than today. During the Last Glacial Maximum, glaciers from the Kodar Mountains barred the course of the Vitim river, forming a 3000 km³ ice-dammed lake (30 times the volume of Lake Lemman), whose catastrophic drainage caused one of the largest glacial outburst floods documented in Earth's history.

Goal: using the numerical, open-source, Parallel Ice Sheet Model (PISM, www.pism-docs.org), to simulate glaciation of the Transbaikalian Mountains under idealized climatic conditions and explore the model sensitivity to changes in input temperature and precipitation. The work will be conducted in collaboration between ETH Zürich (Dr. J. Seguinot) and Vrije Universiteit Brussel (M. Margold).

Laboratory experiment of subglacial drainage: prototype development (Master Thesis)

Subglacial drainage (i.e. melt water flow along the ice-bed interface) has wide-ranging impacts: from dictating glacier sliding speed to determine the hazard potential of ice dammed glacial lakes. Research during the last decades produced tremendous advances in our understanding of subglacial drainage, both through theoretical advances and increasingly sophisticated field experiments. However, direct observations of subglacial drainage processes are impossible and will likely remain so for the foreseeable future. This lack of observations could be overcome by using a physical model of subglacial drainage. Whilst there have been laboratory experiments of other subglacial processes, such as sliding, none have been performed to study water flow. This project will investigate the feasibility of such an experiment by producing a table-top prototype. The model will consist of a flume sealed above by a plunger to pressurise the sediment (and water) contained inside.

Goal: To produce a table-top physical prototype model of subglacial drainage over a sediment bed. This can be used to study the sediment and flow dynamics which lead to channel growth and shrinkage. This thesis will focus on the hydraulic engineering challenges to produce a realistic and working prototype for a larger scale model. Challenges include pressurised drainage and sediments, inclusion of ice and accurate water temperature controls. This work will be in collaboration with the Swiss Federal Institute for Forest, Snow and Landscape Research WSL (Dr. Mauro Werder).

Monitoring the discharge of freshwater at the front of Bowdoin Glacier, Northwest Greenland, using a Unmanned Aerial Vehicle (UAV)



Calving front of Bowdoin Glacier with 2 plumes

In the last decades, many ocean-terminating glaciers from the Greenland Ice Sheet (GIS) experienced thinning and rapid retreat, which in turn affected the global loss of ice and contributed to sea-level rise. Approximately half of the ice ablation of the GIS is due to calving, i.e. the release of icebergs at the edge of glaciers. The calving mechanism is still not entirely understood, mostly because of the complex interconnection between involved processes near the calving front. One of these processes concerns the discharge of meltwater into the ocean. Because of differences in salinity between fresh and tide water, discharging melt water is characterized by highly turbulent flow (called "plume") at the ocean surface next to calving fronts. Such phenomena is known to enhance the submarine melting along the cliff so that the calving face below sea level might be overhanging. In turn this causes the front to lean forward, crevasses to open upstream, and the glacier to calve. Plume models have well developed in recent years to better understand the effects of plumes on subglacial melting. However, these models need velocity data at the surface of the ocean as a boundary condition. Image-based flow velocimetry from UAV (Unmanned Aerial Vehicles) images has proved to be a promising tool to collect such data, the multitude of visual features induced by the transported sediments serving as tracers.

The goal of this work will be to implement this technique to infer and analyse the turbulent velocity fields at the plume of Bowdoin Glacier from aerial images captured by a UAV in July 2016. With 35 UAV flights operated during two weeks, the study will focus on the time variability of the plume activities, and the correlation to some external proxies such as the air temperature and the flow of a torrent located upstream the calving front (Dr. Guillaume Jouvét).