Testing the importance of explicit glacier dynamics for future glacier evolution in the Alps

A Master Thesis Exposé

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Description

In recent years there has been a growing interest in modelling glaciers at regional and global scales. The models have increased in complexity, and two of them now include an ice dynamics module (Maussion et al. 2019; Huss and Hock 2015). This makes sense for large glacier complexes or for complex processes such as calving, but in the Alps the glaciers are small and likely to melt in the future decades.

This raises the question: how much complexity is really needed for projections of glacier evolution in the Alps?

In this thesis the Master Student will realize regional runs with the Open Global Glacier Model (www.oggm.org) and ask the research question above.

The tasks will include:

- the implementation of a simpler glacier evolution module in the OGGM codebase (Marzeion et al. 2012)
- maybe: the implementation of an intermediate glacier evolution module (Huss and Hock 2015)
- realize commitment and/or projection simulations in the Alps
- analyse the results

I am looking for a motivated student, able to program in Python and interested in Alpine glaciology.

1 Introduction

2 State of the art

Glaciers form in areas where the amount of fallen solid precipiation exceeds its melt over the course of time i.e. where water mass in form of ice (and firn) accumulates. Thereby, glaciers act as low pass filters, smoothing the daily, monthly and yearly variablities of the climate system and making slow changes over decades visible to the eye. Hence, the constant retreat of glaciers over the last years is a clear sign of global warming. And while the amount of ice stored in glaciers is small compared to the ice stored in the Greenland and Antartic ice sheets, its contribution to the observed sea level rise is non neglibile. ?CITATION Given the fact that direct runoff measurements for all glaciers are impossible, glacier modeling is frankly the only way to estimate glacier ice volume and its response to a changing climate.

The ice volume is the most important glacier property and yet the least known about. Given that it is difficult and labourious to measure, it is necessary to infer parameters hidden within the glacier (e.g., ice thickness, basal velocities, ...) from surface values (e.g., surface area, surface velocities, ...). While a forward problem can be classified as using a model with given parameters to generate data, deducing the model parameters that produce the given data is refered to as an inverse problem. Inverse problems are quite common in the field of geophysics, where the goal is to determining geological structures from geophysical fields (i.e., gravitiational field, magnetic field, ...) (Zhdanov 2002) However, such inverse problems with unbalanced boundary conditions are prone to unstable and non-unique solution, also called ill-posed problems. And the ice thickness inversion is

foreward problem: predicting glacier evolution from given glacier geometries and mass balance data. inverse problem: infer the glacier geometries from glacier evolution

Scaling and similarity theory are widely used throughout science - Buckingham Pi Theorem

While glacier volume-area scaling was initially introduced as empirical concept (Chem Omugura, Makarov, ...),

Bahr et al. (2015) reviewed over 30 recent publications either concerned with or applying volume-area scaling techniques.

the following guidelines, some of which are directly beneficial to the Alps as study site:

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- "Apply volume-area scaling to collections of many glaciers, not to individuals. Treat the resulting set of volumes as a probability distribution"
- "Include time dependence by using response time scaling"
- "Avoid applying volume-area scaling to glacier complexes"

3 Research question

The main research question reads **"How much complexity is really needed for projections of glacier evolution in the Alps?"**

One would think, the more complex the model, the better its representation of reality and therefor the more reliable the produced outcome. However, there are some caveats with this proposition. First and most obviously, increasing model complexity increases the computational cost of a simulation. And while we live in times of exascale computing (see Folding@Home), unfortunately there is no iPhone app projecting global glacier evolution over decades just yet. Secondly, a model is per definition be a simplifaction of reality and thereby some uncertainties are introduced. And lastly, while glacier dynamics and their response to the climate system are generally well understood, the uncertanties arising from imperfect input data, or simply the lack thereof, have a considerable effect. At some point more data are adding noise much rather than information.

as much as needed but as little as possible

Glacier volume-area scaling and glacier response

1. How does the volume-area scaling model compare to the shallow ice flowline model?!

2.

4 How I'm doing my research

4.1 Theory and sensitizing concepts

4.2 Research field, data and methods of data collection

4.3 Methods used in data analysis

4.4 Timeline

References

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