universität innsbruck

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

Moritz Oberrauch (*moritz.oberrauch@uibk.ac.at*), Fabien Maussion

Volume-area scaling vs. shallow ice approximation

Even though the **Open Global Glacier Model (OGGM)** is a rather simple model (concerning the implemented physics), the **volume-area scaling (VAS) glacier model** originally used by Marzeion et al. (2012) is even more basic. While the OGGM implements shallow ice approximation to drive the model glacier, the VAS model relies solely on volume/area and volume/length scaling principles.

What am I doing?! Currently I'm implementing the original volume/area scaling model used by Ben (at least I'm trying to).

Why am I doing it?! More complex models generelly come with higher computational costs. While this may be necessary for certain detailed analysis, not all scientific questions call for such a high degree of accuracy. In addition, alpine glaciers will most likely not advance much in the coming decades. Hence, ice dynamics play a secondary role compared to ice melt.

What do I want to achieve?! In a nutshell: how far can I dumb the dynamic model down, while still producing reasonable results on a regional scale. To do so I will:

1. implement glacier model(s) with different levels of complexity in the OGGM framework.
2. investigate the strengths and weaknesses of the VAS model approach (sensitivity analysis).
3. complete regional comittment runs for the alpine region (past and future).

Mass balance model

The mass balance model implements a the **temperature index model**.

$$B(t) = \left[\sum_{i=1}^{12} \left(P_i^{\text{solid}} - \mu^* \cdot \max(T_i^{\text{teminus}} - T_{\text{melt}}, 0)\right)\right] - \beta^* \qquad (1)$$

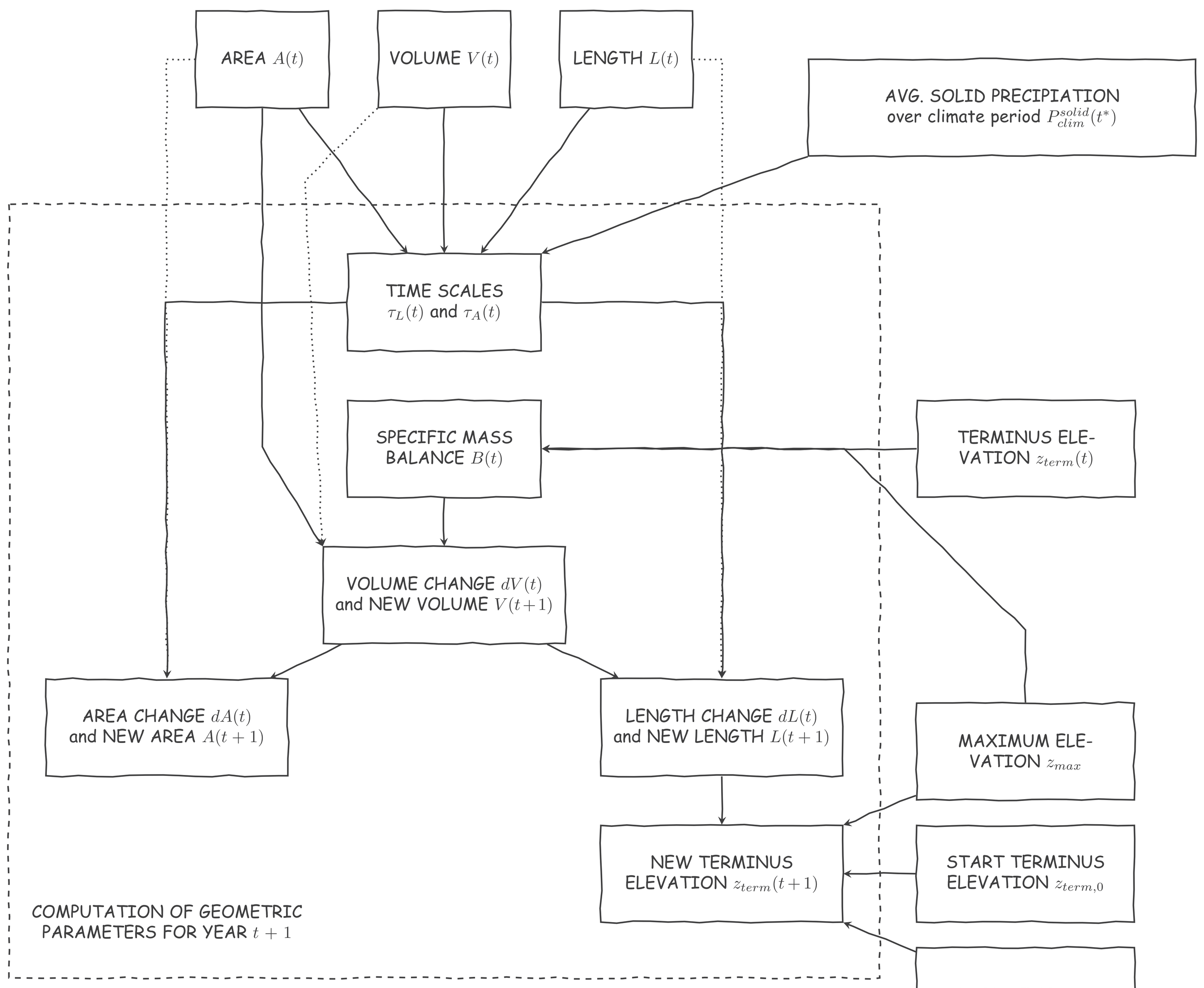
The annual specific surface mass balance $B(t)$ is computed as the difference of monthly solid precipitation fallen onto the glacier surface P_i^{solid} (mass input) and monthly positive melting temperature at the glacier terminus T_i^{teminus} (energy input), summed over a year. The temperature sensitivity parameter μ^* needs to be calibrated for every single glacier. Additionally, a mass balance bias β^* can be added/subtracted.

The scaling model

The used scaling laws are quite basics:

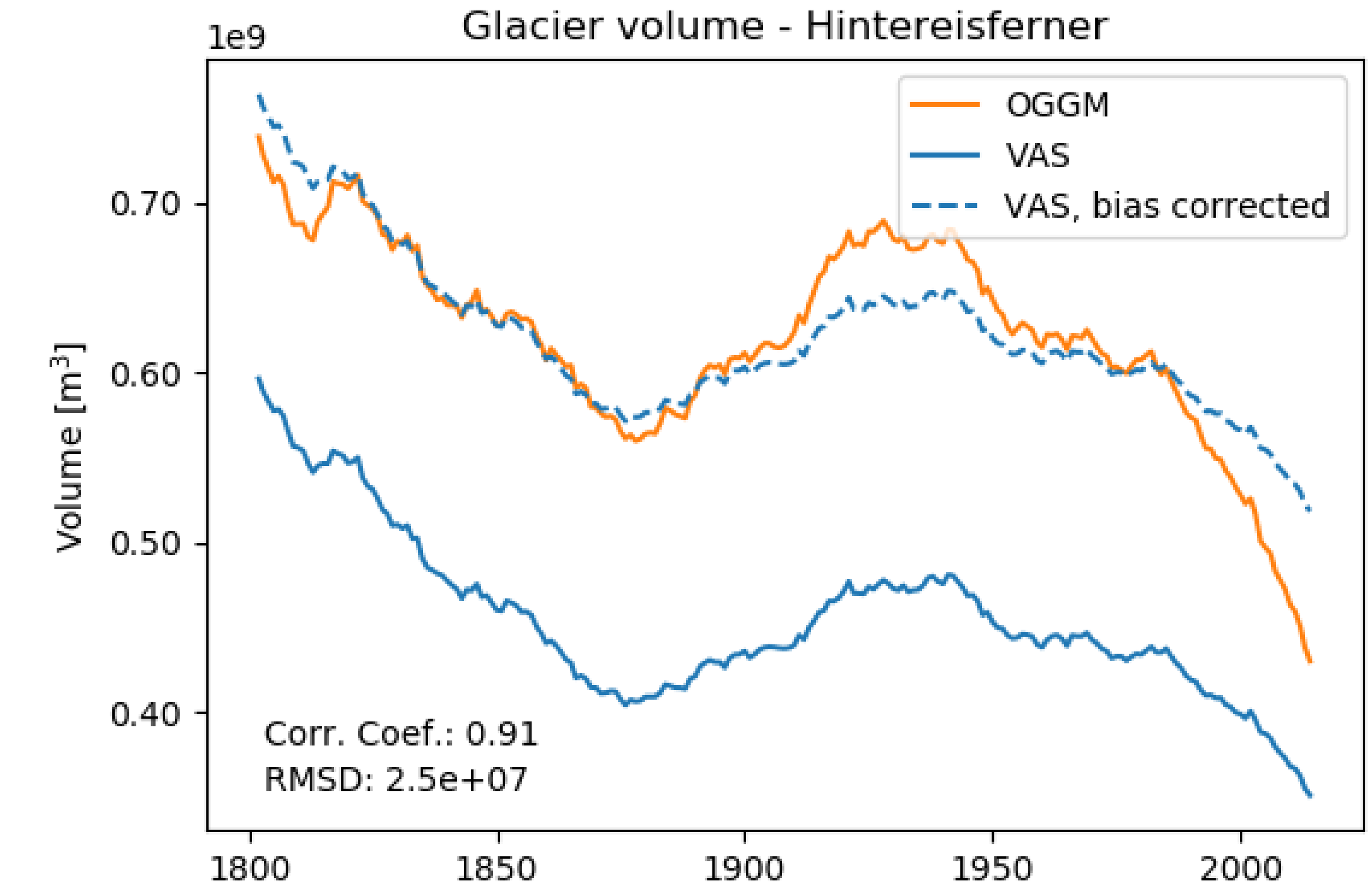
$$V(t) = c_A \cdot A(t)^\gamma, \qquad V(t) = c_L \cdot L(t)^q \qquad (2)$$

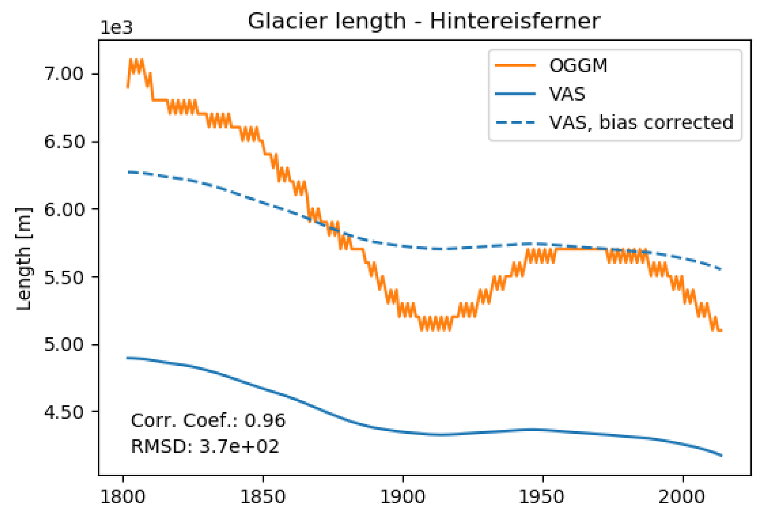
where c_A, c_L and γ, q are scaling parameters. For each year t the volume change $dV(t)$ is computed, given the specific mass balance $B(t)$ and the surface area $A(t)$. The resulting new volume $V(t+1)$ is used to compute the area change dA and length change dL, scaled by the corresponding response time τ_A and τ_L, resp. A change in glacier length $L(t+1)$ translates into a change in terminus elevation $z_{\text{term}}(t)$, which influences the specific mass balance $B(t+1)$.

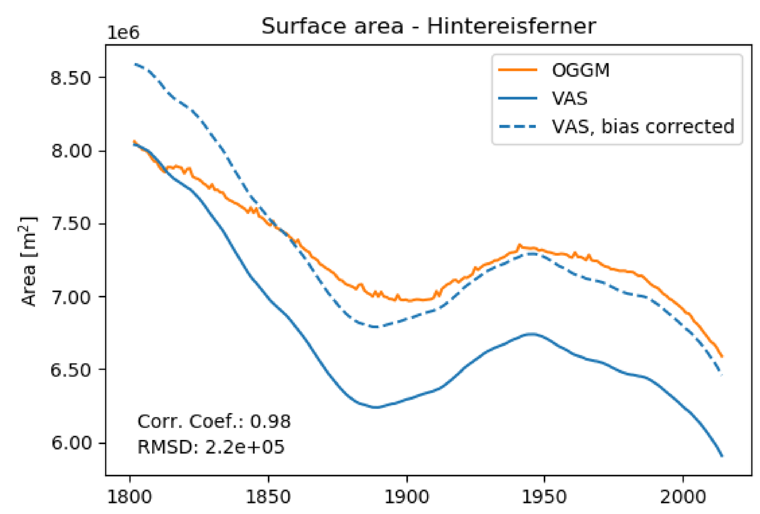


Comparing the model performance on a single glacier

Both models are initialized with the glacier outline of Hintereisferner in 2003 (RGI Consortium, 2017), without any spinup. The models run from 1802 to 2014 using the HistAlp climate data (Auer et al., 2007) as input. Hence, the shown glacial evolution is a predominantly **qualitative result**, not comparable with the actual evolution of the Hintereisferener.







First small scale regional run - Rofental

Let's see if I produce something sensible here, until it has to be printed...

```
../plots/rofental.png
```

What next?!

Given that this is just the first implementation step, the (qualitative) results are quite promising. However, some more work is required before deriving any conclusions. This includes the following tasks/questions:

- Does the length change have to be comparable?!
- Finding appropiate/sensible start values...
- Performance test against reference glaciers.
- Regional (alpine) runs
- Sensibility analysis

References:

Auer, I., et al., 2007: HISTALP—historical instrumental climatological surface time series of the Greater Alpine Region. *International Journal of Climatology*, **27 (1)**, 17–46, doi:10.1002/joc.1377, URL http://cdiac.esd.ornl.gov/oceans/GLODAP/glodap{_}pdfs/Thermohaline.web.pdfhttp://doi.wiley.com/10.1002/joc.1377.

Marzeion, B., a. H. Jarosch, and M. Hofer, 2012: Past and future sea-level change from the surface mass balance of glaciers. *The Cryosphere*, **6 (6)**, 1295–1322, doi:10.5194/tc-6-1295-2012.

RGI Consortium, 2017: Randolph glacier inventory – a dataset of global glacier outlines: Version 6.0: Technical report: Global land ice measurements from space, colorado, usa. URL http://www.glims.org/RGI/, doi:10.7265/N5-RGI-60, URL http://www.glims.org/RGI/.

Acknowledgements:
My thanks go to Ben Marzeion for clearifying some definitions and for supplying me with his original code base. Additional thanks go to my supervisor, Fabien Maussion.