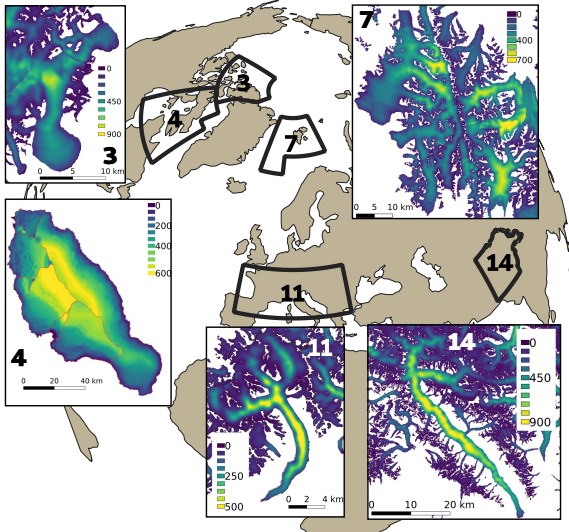# BITE
The Bayesian Ice Thickness Estimation model

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Modelling ice thickness maps

BITE-modelled thickness of Unteraar Glacier with superimposed radar-measured thickness (white-framed)

- ice thickness is needed for ice flow modelling, hydrological forecasts and sea-level rise projections
- various models have been proposed to do this
  (see overview in Farinotti & al, 2017)

This work is published in Werder & al. (2020)

A Bayesian ice thickness estimation model for large-scale applications
Journal of Glaciology 66(255), 137–152.
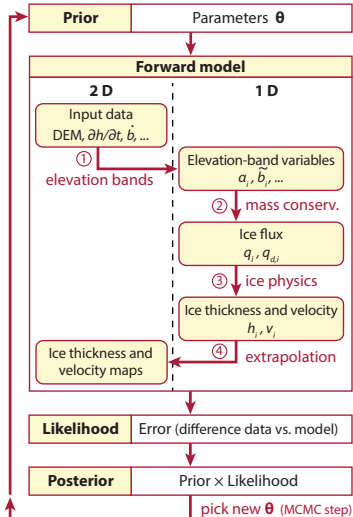
We combine an established forward model with a Bayesian inversion scheme.

- forward model of Huss & Farinotti, 2012 based on mass conservation, the shallow ice approximation, and empirical relations
- stochastic model posits that model errors have a normal distribution

(A) flow line geometry: given surface and modelled bed (with uncertainty). (B) modelled surface flow speeds (with uncertainty). (C) Distribution of mean glacier thickness. (D) scatter and histogram plots of fitted parameters.

Bayesian model

Bayes for parameters θ and data d:
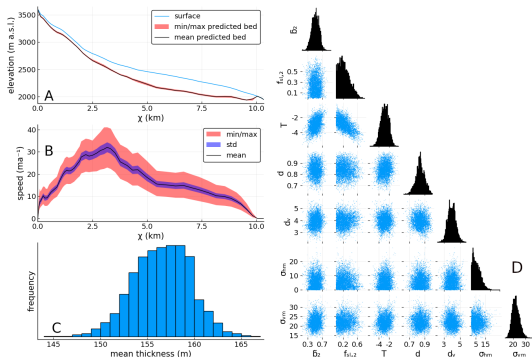
$$p(\theta|d) = \frac{p(d|\theta)\, p(\theta)}{p(d)},$$

Likelihood:

$$p(d|\theta) \propto \underbrace{\frac{1}{\sigma_{\mathrm{h}}} \mathrm{e}^{-\frac{\sum (h(\theta) - h')^2}{2\sigma_{\mathrm{h}}^2}}}_{\text{thickness error}} + ...$$

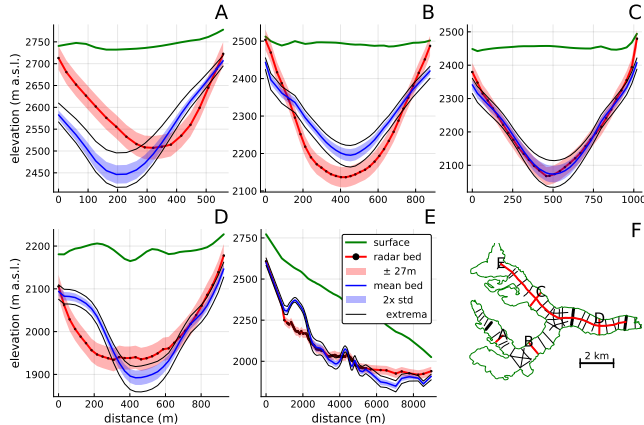Priors (θ) for the model parameters θ given by other models and measurements.

Using MCMC method to calcualte the distribtion of θs and make predictions – including uncertainties – for thickness and surface speed.

Modelled (blue) vs measured (red) ice thickness at selected profiles (marked as red lines in panel (F)). The three thick black lines are the tracks used to fit the model.

The model is fitted to Unteraar Glacier to show-case.

- model fits data relatively well
- model as setup is limited to one profile shape, modified by surface features

Results: regional application

The model was applied to all glacier from five RGI regions, amounting to ~30'000 glaciers.
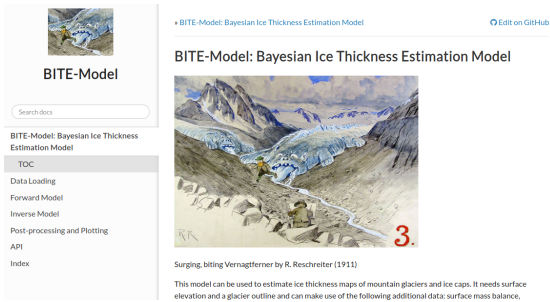
The comparison to the recent consensus estimate from the G2TI study (Farinotti & al., 2019) shows good agreement:
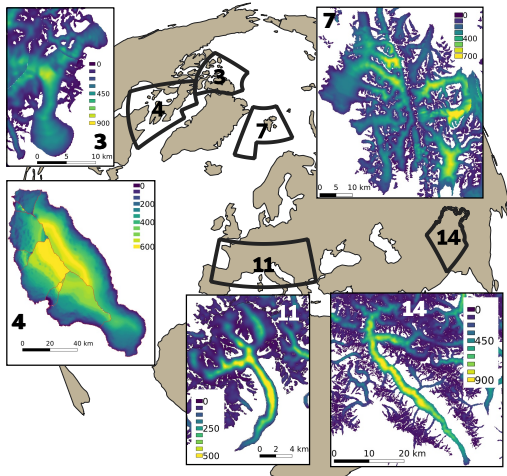
Globe with the five RGI regions marked. Insets show example thickness maps from each region.
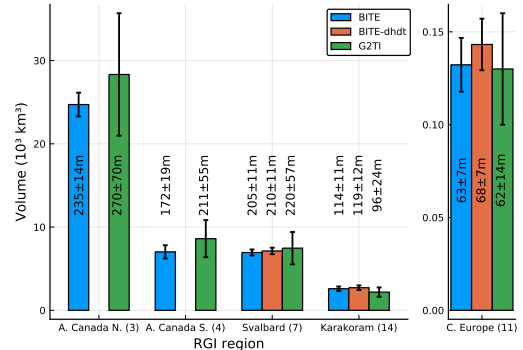
Conclusions

Documentation of BITE model. Code hosted on
`https://github.com/mauro3/BITEmodel.jl`

- BITE model performs as well as the best other models

- However, ice surface flow speeds are not improving the assimilation :-(

- How to best transfer parameters from glaciers with ample measurements to others with no or few measurements is not clear yet

- applied to 30'000 glaciers requiring the calculation of 10^8 ice thickness maps

- Model is open source, written in Julia

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A Bayesian ice thickness estimation model for large-scale applications. Journal of Glaciology 66(255), 137–152.