Impact of spatial resolution on large-scale ice cover modeling of mountainous regions

Helen Werner[1], Dirk Scherler[1,2], Ricarda Winkelmann[3,4], Guillaume Jouvet[5]

[1]GFZ German Research Centre for Geosciences, Germany, [2]Freie Universität Berlin, Germany, [3]PIK Potsdam Institute for Climate Impact Research, Germany, [4]University of Potsdam, Germany, [5]University of Lausanne, Switzerland

Introduction

For reconstructing paleoclimate or studying glacial isostatic effects on the Earth's lithosphere, increasingly more studies focus on **modeling the large-scale ice cover in mountainous regions over long time scales**.

How well are **high peaks** and **steep slopes** resolved?

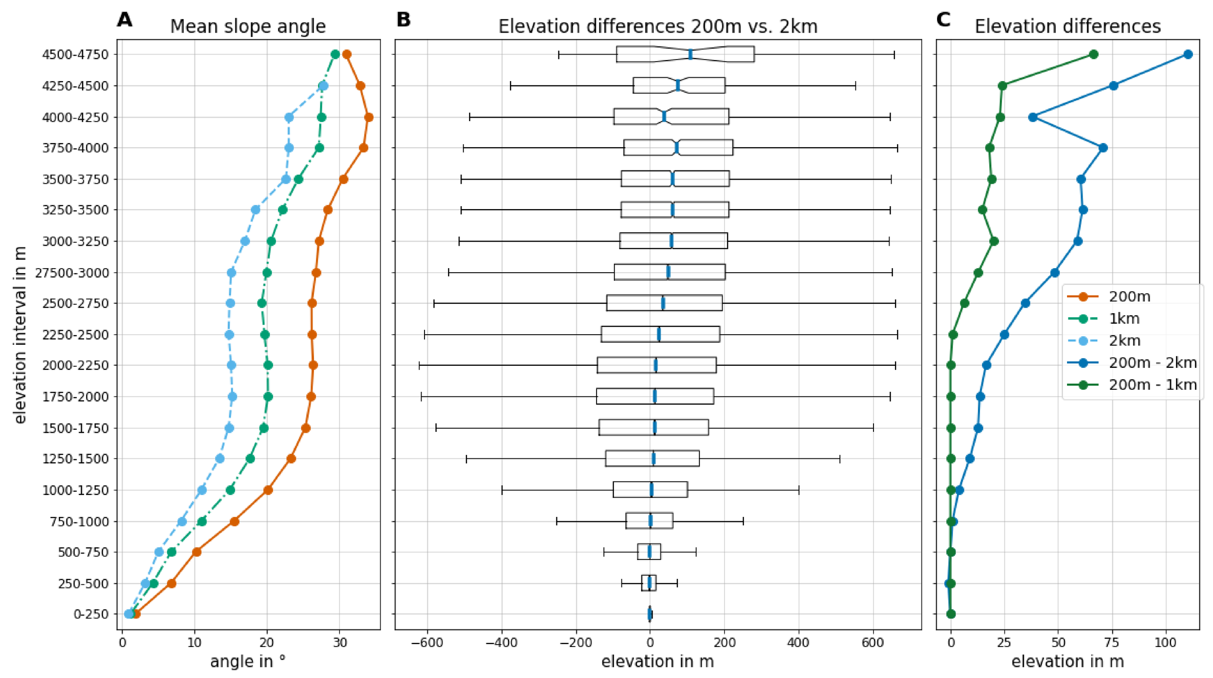

*Fig. 1: **A**: Slope angle with respect to elevation intervals. **B** and **C**: elevation differences based on the 200 m topography in relation to elevation intervals*

Previous studies of large-scale ice cover simulation in mountain areas such as the European Alps, New Zealand, and the Tibetan Plateau, typically used km-scale resolution.

However, high peaks and steep slopes which are crucial for glacier mass balance and dynamics, are poorly resolved in coarse resolution topography.

Methods

Experiment Setup

- Topography[2] of the entire **European Alps** (covering 480 240 km^2)
- Present day climate with linear cooling rate until 6 ℃ colder
- Simulate the expanding ice cover over a time period of 160,000 years

The Instructed Glacier Model (IGM)

- Open source ice model: https://github.com/jouvetg/igm
- Novel 3D ice model equipped with a *Convolutional Neural Network* (CNN) trained from high order models to simulate ice flow
- Significant acceleration of run times

→ Possibility of **running in higher spatial resolution**

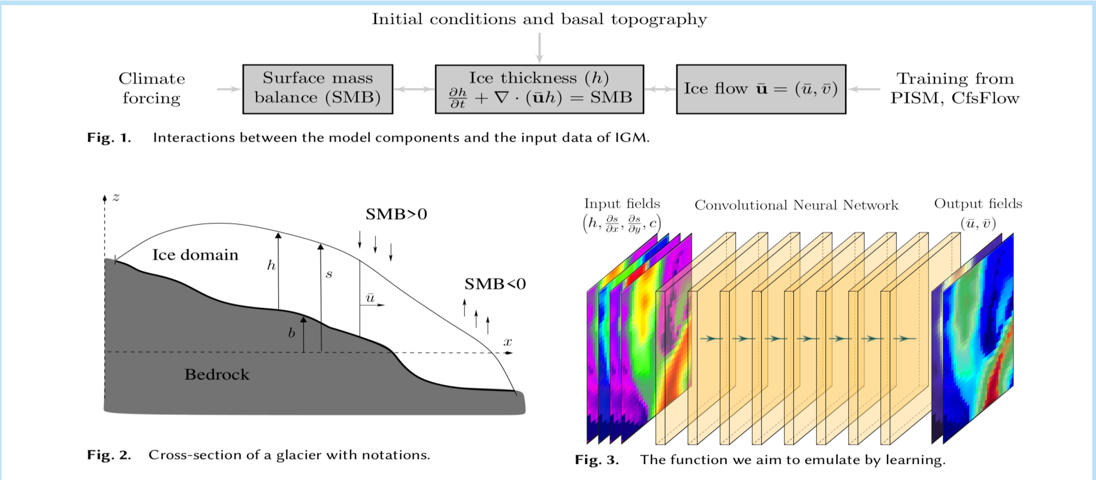

Fig. 2: IGM model components, notations, and function of CNN, by Guillaume Jouvet[1]

Results

The 200 m model yields ~13.4% **more total ice volume** than the 2 km model.

With 1 km resolution we have ~3.4% less ice volume than with the 200 m model and ~10.4% more volume than with 2 km resolution.

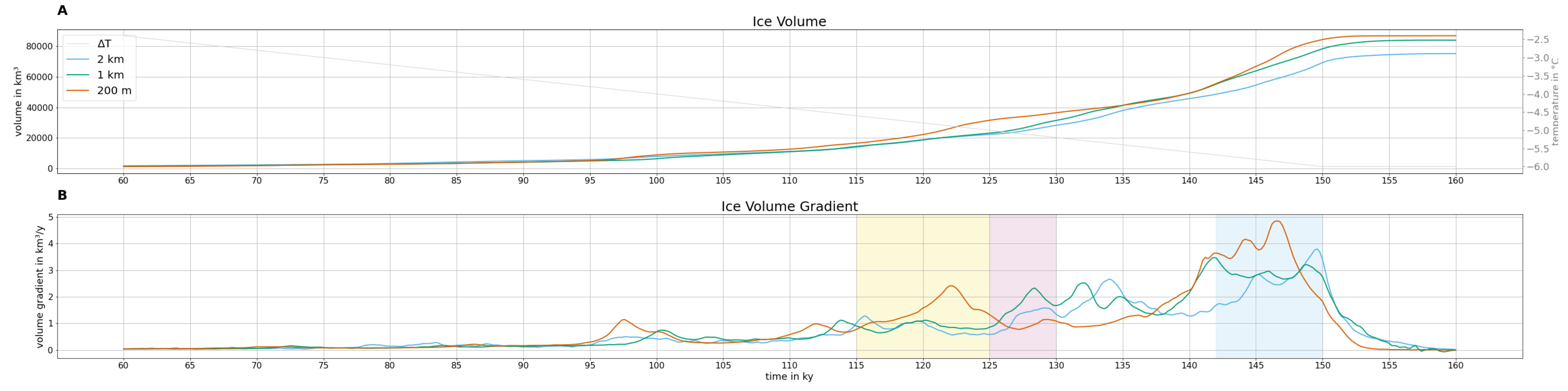

*Fig. 3: Ice volume of the different resolution models and temperature forcing (**A**). Ice volume gradient with growth phases (yellow, red and blue) (**B**)*

In **growth phases**, there is a temporal offset in some regions.

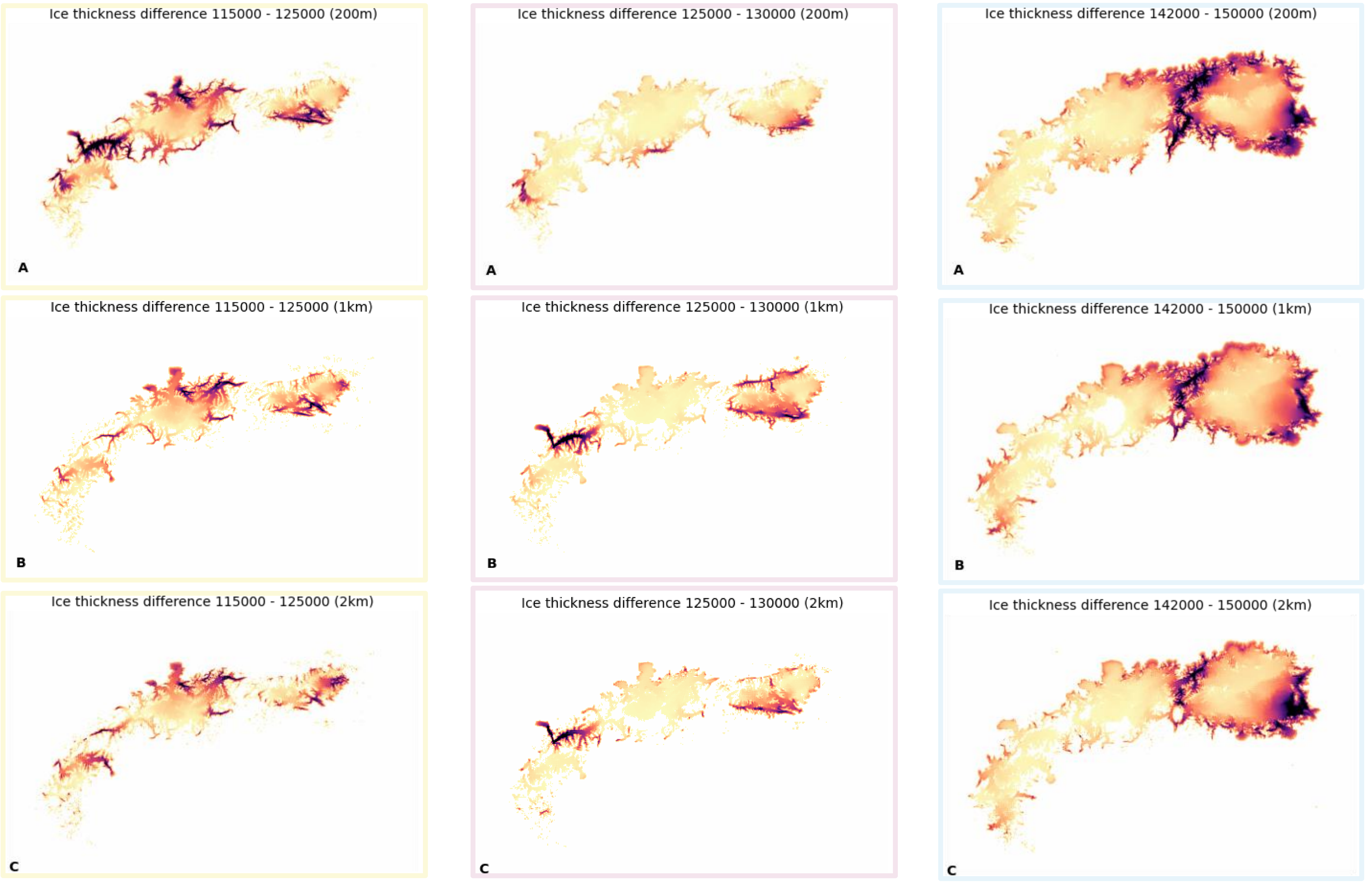

*Fig. 4-6: Spatial distribution of ice thickness during ice growth phases as marked in Fig. 3 (lower panel, yellow, red, blue) for 200 m (**A**), 1 km (**B**), and 2 km (**C**)*

The differences in ice volume are **not uniformly distributed in space**.

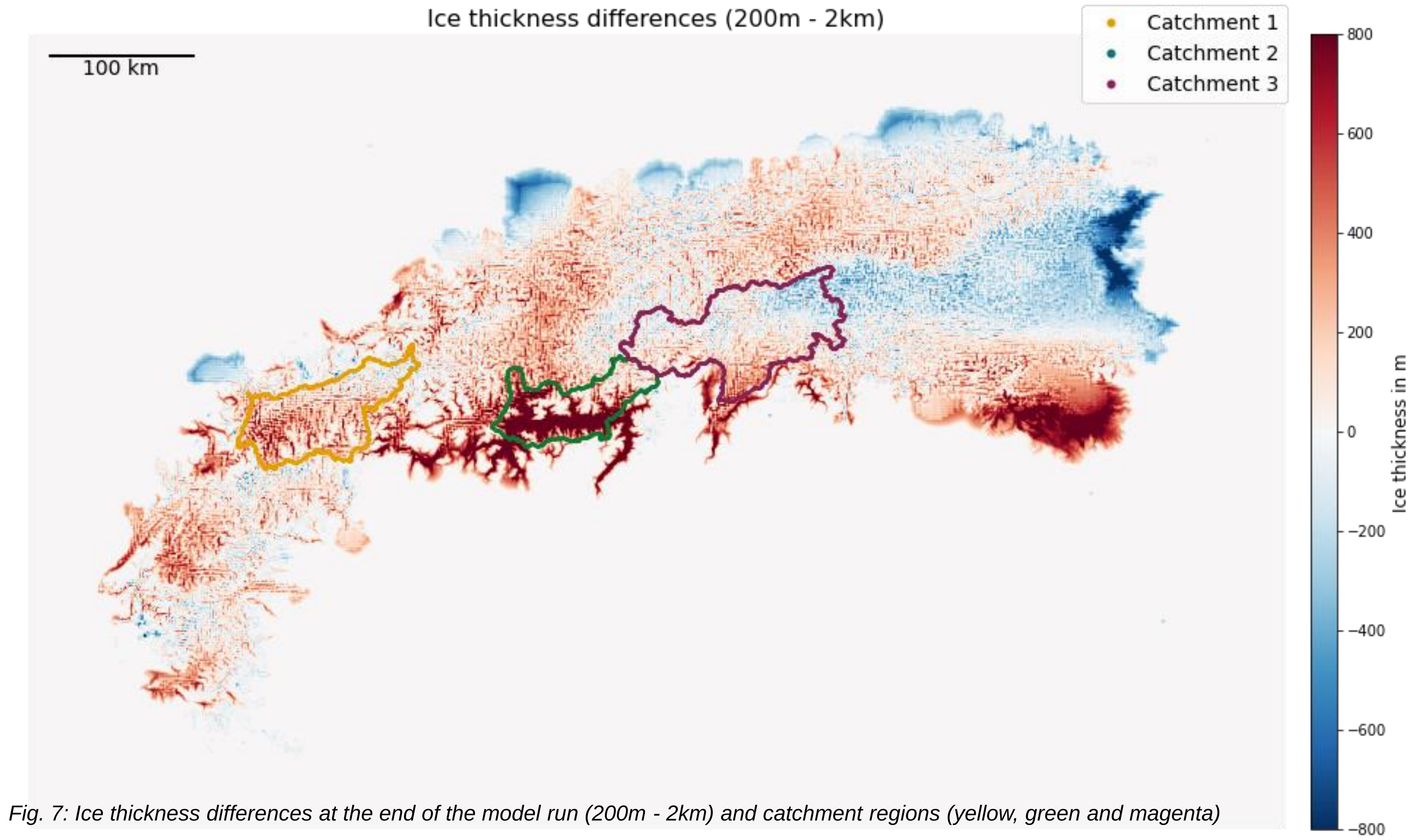

Fig. 7: Ice thickness differences at the end of the model run (200m - 2km) and catchment regions (yellow, green and magenta)

For **most regions**, the higher resolution model yields more ice.

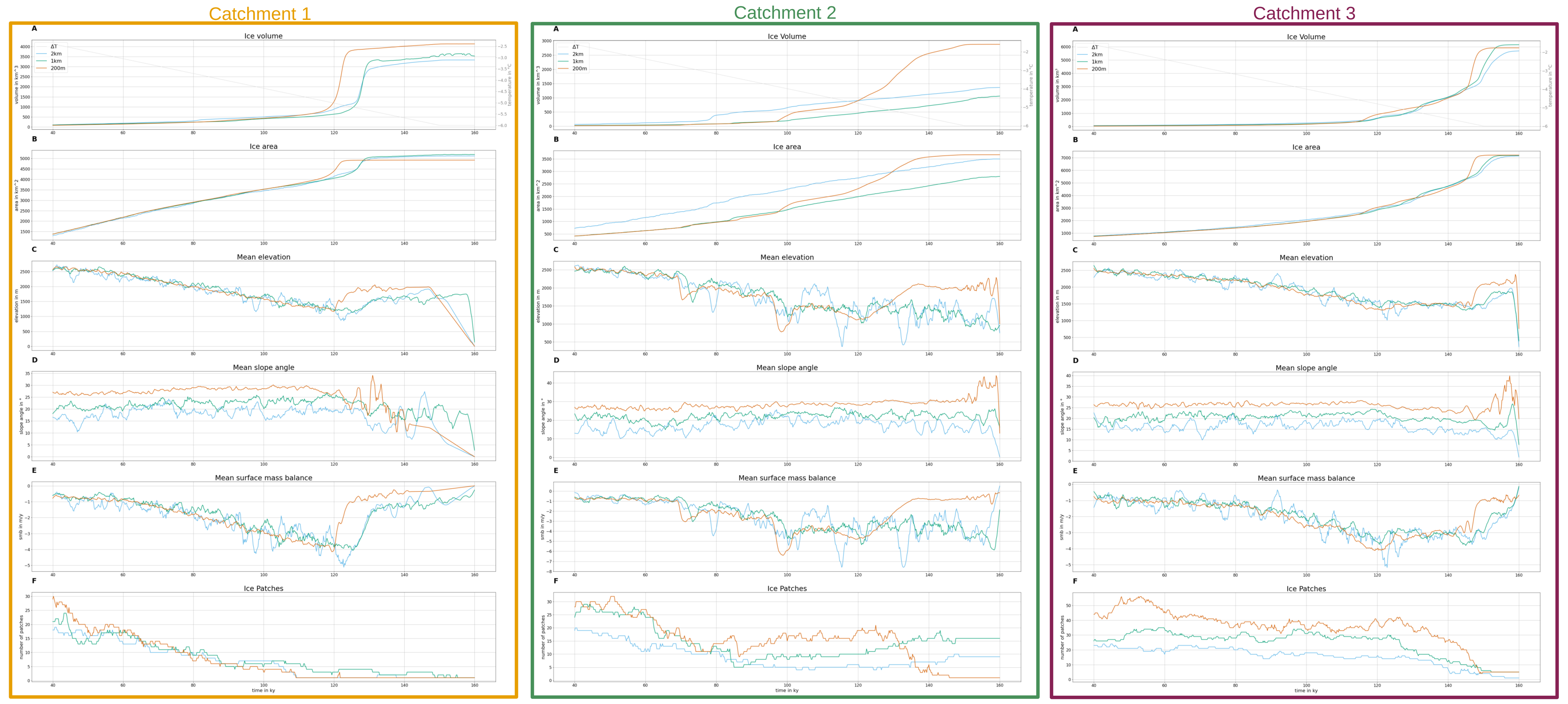

*Fig. 8-10: Ice volume of the different resolution models and temperature forcing (**A**), ice area (**B**), mean elevation, slope angle, surface mass balance of points that will be ice covered in the next time step (**C**-**E**), number of ice patches (**F**) for different catchment regions (yellow, green and magenta) as outlined in Fig. 7*

References

1) Jouvet, G., Cordonnier, G., Kim, B., Lüthi, M., Vieli, A., & Aschwanden, A. (2021): Deep learning speeds up ice flow modelling by several orders of magnitude. Journal of Glaciology, 1-14. doi:10.1017/jog.2021.120
2) Mey, J., Scherler, D., Strecker, M.R., Zeilinger, G. (2015): Estimating the fill thickness and bedrock topography in intermonate valleys using artificial neural networks. Journal of Geophysical Research Earth Surface, vol. 120(7), p. 1301-1320, doi:10.1002/2014JF003270
3) Fick, S.E. and R.J. Hijmans, 2017. WorldClim 2: new 1km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37 (12): 4302-4315.

This work is funded by DFG

Sharing not permitted

EGU23-4200
Scan for abstract

Get in touch:
helen.werner@gfz-potsdam.de