

# The Ice Data Hub as a powerful interface between data and simulations

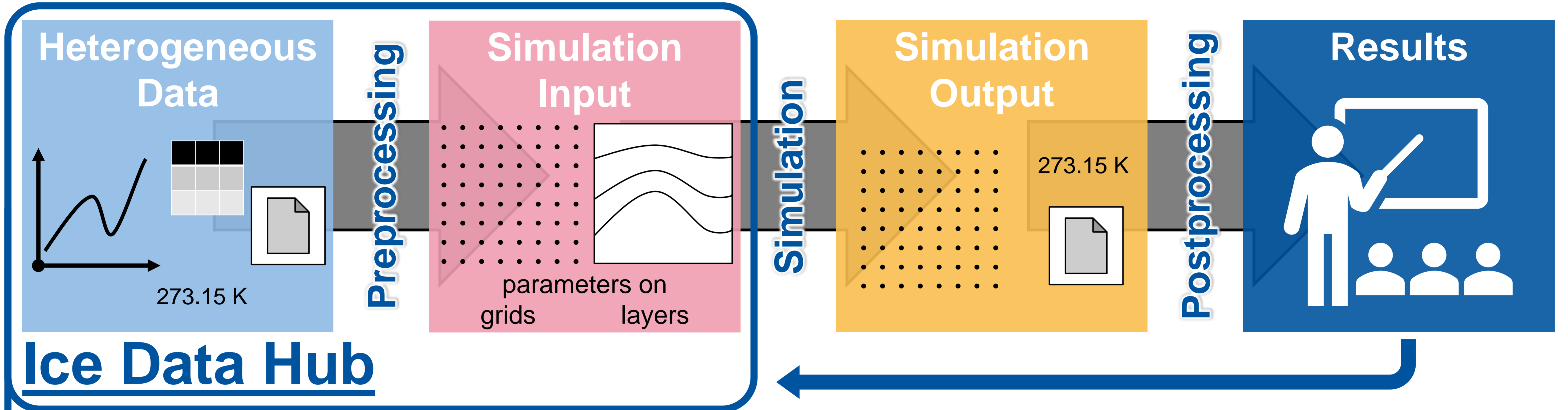
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## Introduction

Providing measurements for scientific simulation software often requires tedious manual preprocessing of data sets. To overcome this problem and to facilitate the access of heterogeneous data sets by simulation tools directly, we have developed the Ice Data Hub.

The Ice Data Hub combines available data from Earth or other planetary bodies including their metadata [1] and allows it to be displayed, interpreted and exported. Most important is its functionality as an interface between data and simulation tools. For example, we develop models for thermodynamic melting processes that can evaluate measurement data directly thanks to the Ice Data Hub. It can also be used as a black box, where a simulation tool queries the Hub to provide a property. This could, for example, be a material property at a certain depth. The accessing functionality for the user is wrapped in the sense that the user uses similar routines, regardless the format of data, e.g., analytical expression, look-up table or interpolant.



## Data Handling

- 1 Data Management
- 2 Data Processing
- 3 Data Crawler
- 4 Data Export
- 5 Python Module

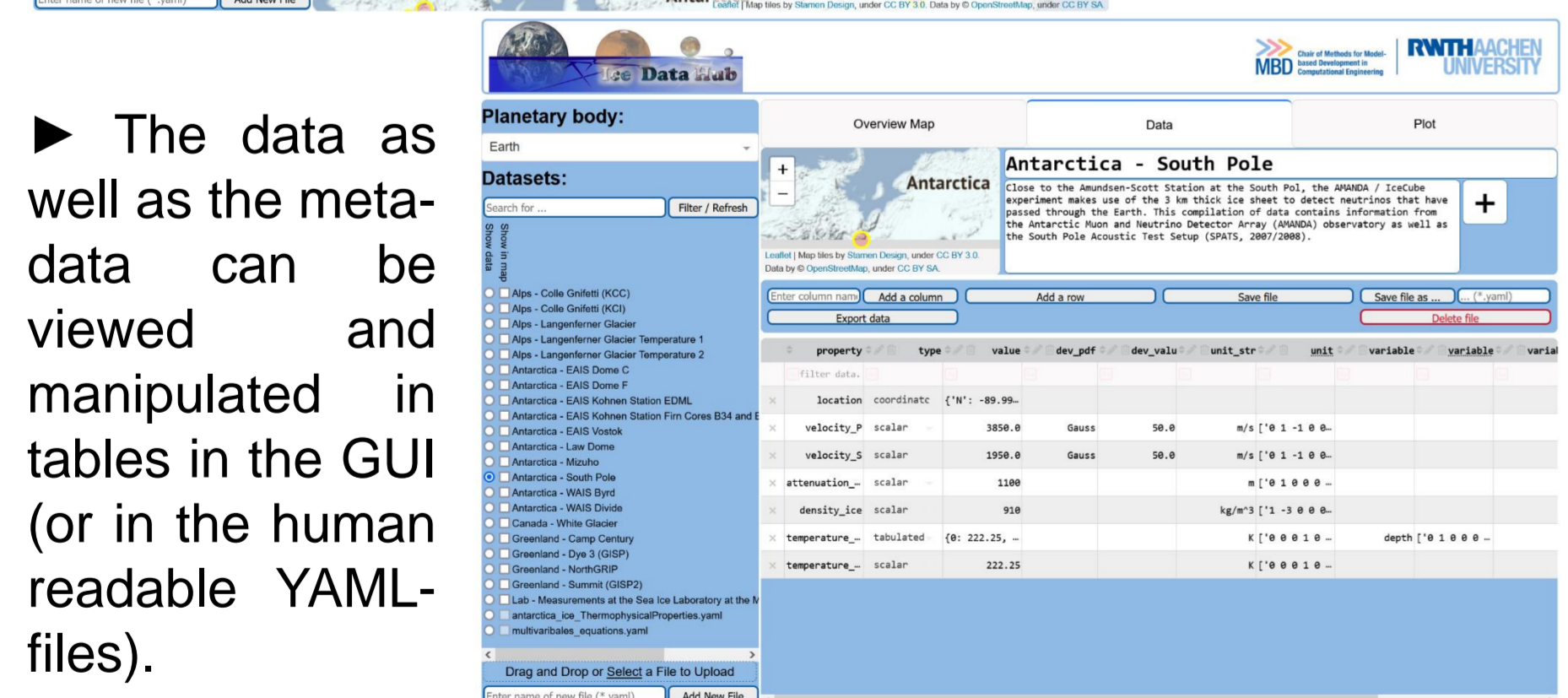
The Ice Data Hub's data is stored in human readable YAML files, each representing one location that allows for (meta-)data enrichment (i.e., adding information on instruments, ice type and spatial resolution).

Data management (1) and processing (2) can be done using a GUI or native Python language. The GUI provides a data crawler (3) that allows to search for datasets. In general, there are two ways to provide data for simulation software. One way is to simply export data (4) in a format that can directly be used for simulation software via the GUI or a Python script. However, more advanced is the second way. The Ice Data Hub is a Python module (5) that can be imported to simulation software. This way, the hub can be used for data management directly.

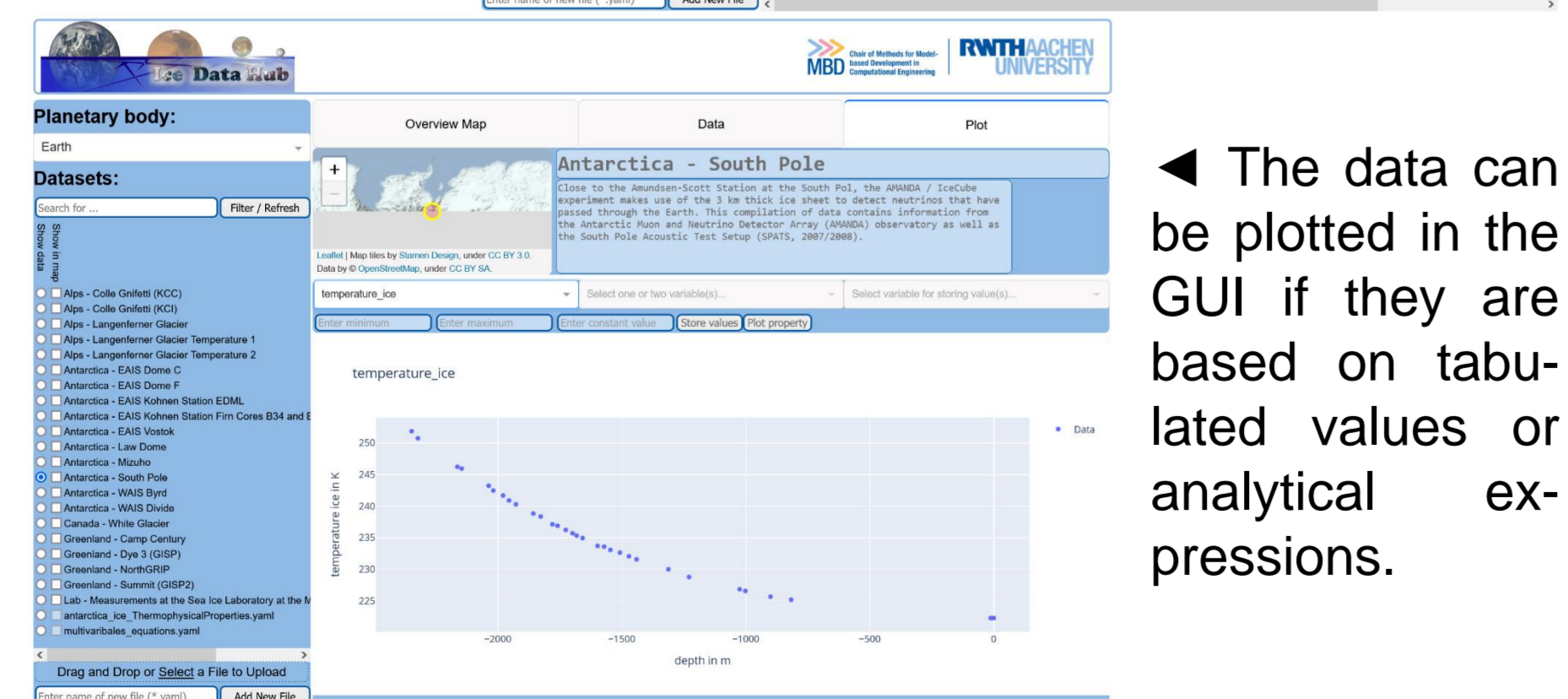
## Web-based GUI



◀ Datasets can be viewed in a list or on a map. This works for data from Earth as well as from other planets or icy moons in our Solar System.



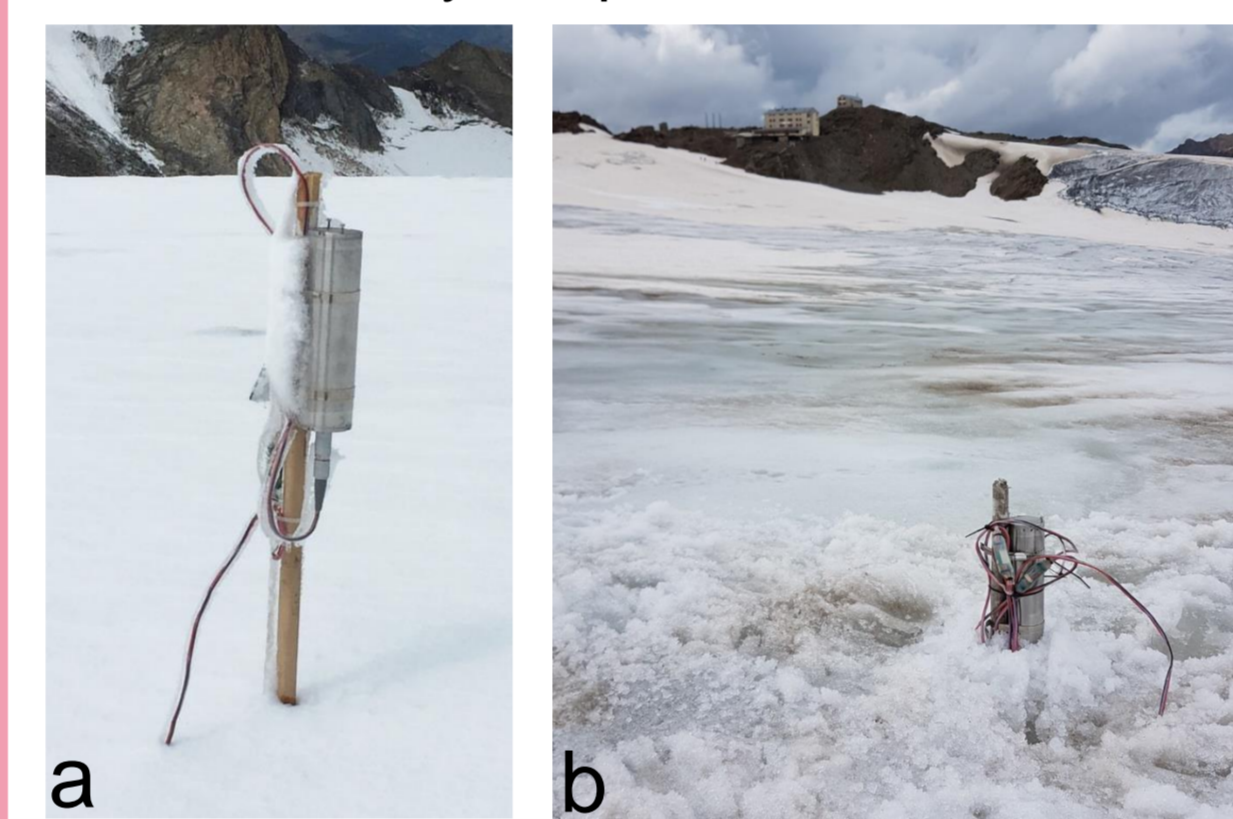
▶ The data as well as the meta-data can be viewed and manipulated in tables in the GUI (or in the human readable YAML-files).



◀ The data can be plotted in the GUI if they are based on tabulated values or analytical expressions.

## Example: Temperature Modelling

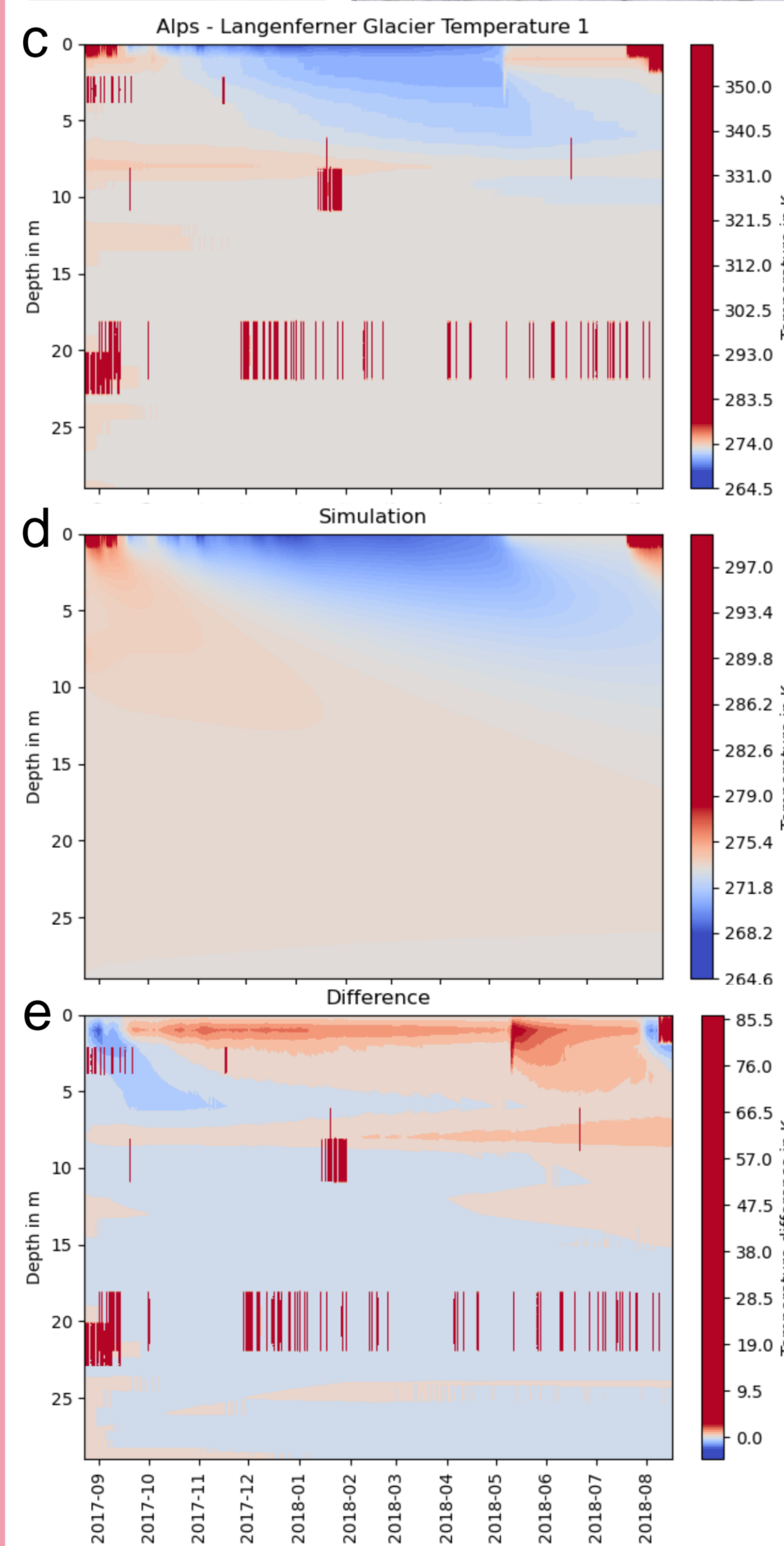
We installed temperature sensors (a, b) in the Langenferner Glacier, Italy. They are distributed with a spacing of 1 m and recorded hourly temperature measurements for about a year (c).



We consider the 1-D transient heat equation,

$$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial z^2},$$

where  $\alpha = \frac{\kappa}{\rho c_p}$  is the thermal diffusivity and we apply a centered finite difference scheme in space and a Crank-Nicolson method to discretize the time. We use the initial readings  $T(z, t=0)$  and the surface temperature  $T(z=0, t)$  as well as the mean temperature at the bottommost sensor  $\bar{T}(z=29m, t)$  as boundary conditions to simulate the temperature evolution with time (d).

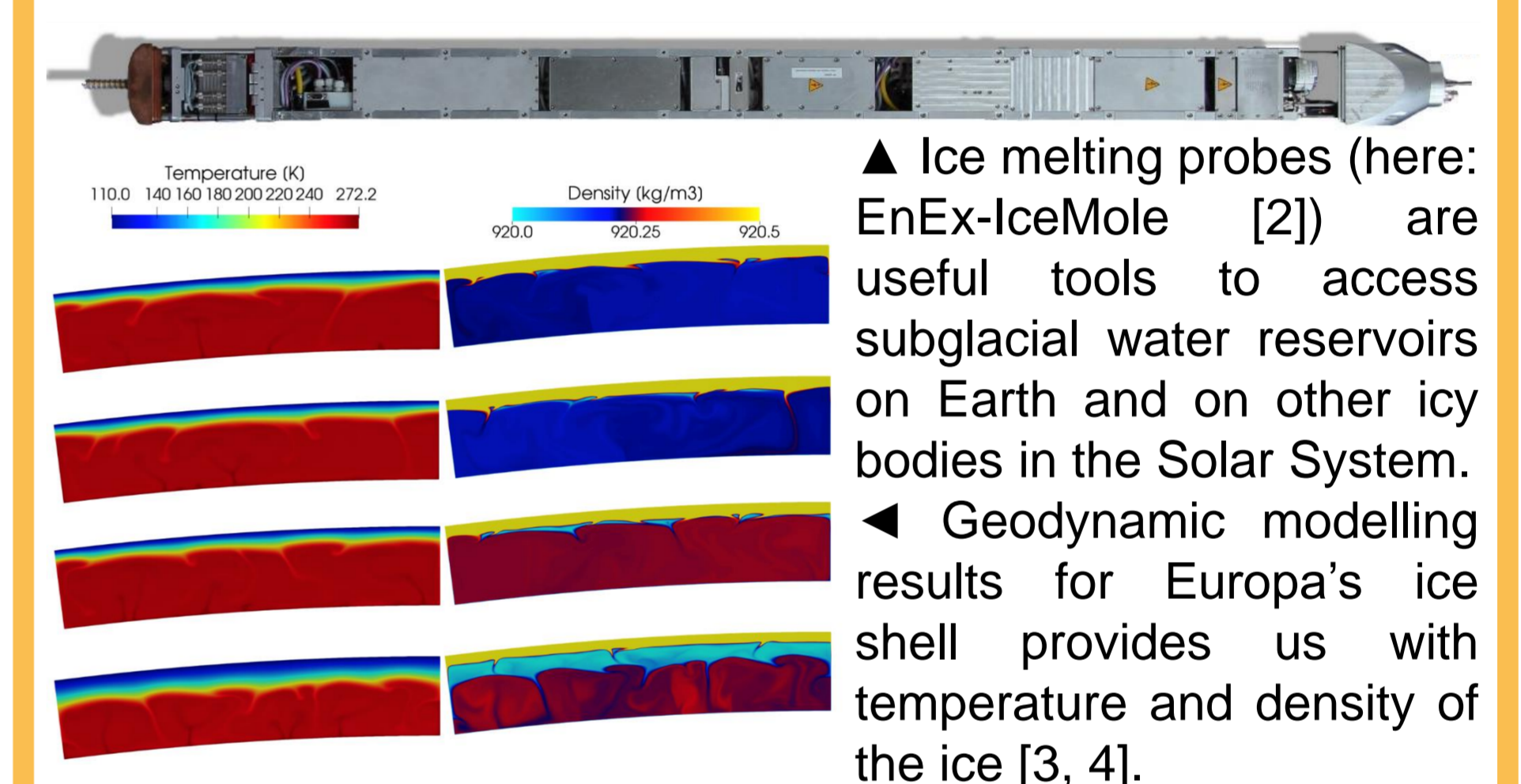


We assume that the glacier consists of pure homogeneous ice. Despite the general agreement of the data and simulation, notable differences occur especially in May 2018, where it is likely that rain infiltrated the porous upper parts of the glacier and led to an increased temperature.

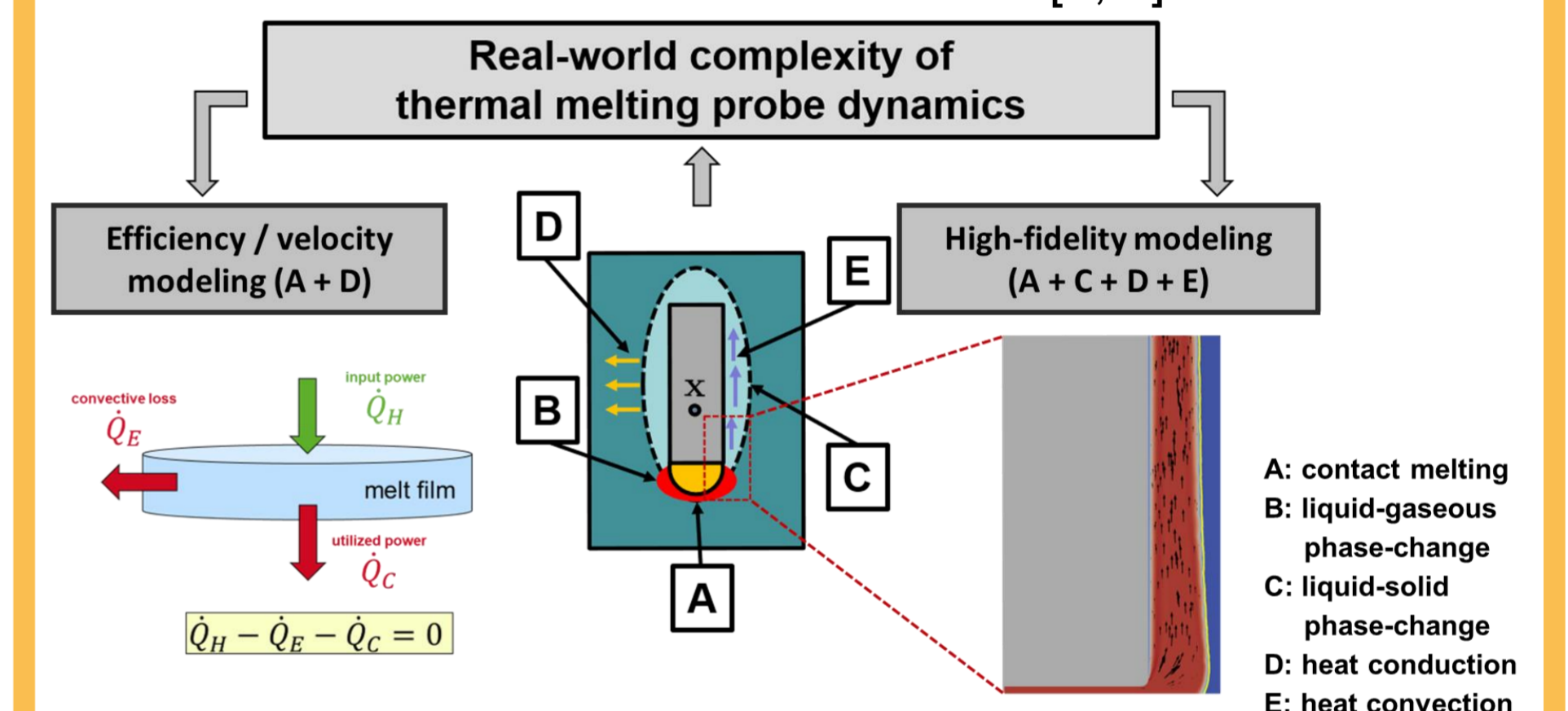
Furthermore, the temperature is higher than expected during the winter. This might be due to a lower density (snow, firn) resulting in an increased diffusivity that is not captured by the simulation with constant parameters. Lastly, when the data was collected in summer 2018, it was observed that the first two sensors were located above the ice (b) due to melting in the summer (also visible in a with the high temperatures above 0°C starting mid July).

In subsequent work, it is possible to implement an inversion to derive material properties from the temperature measurements.

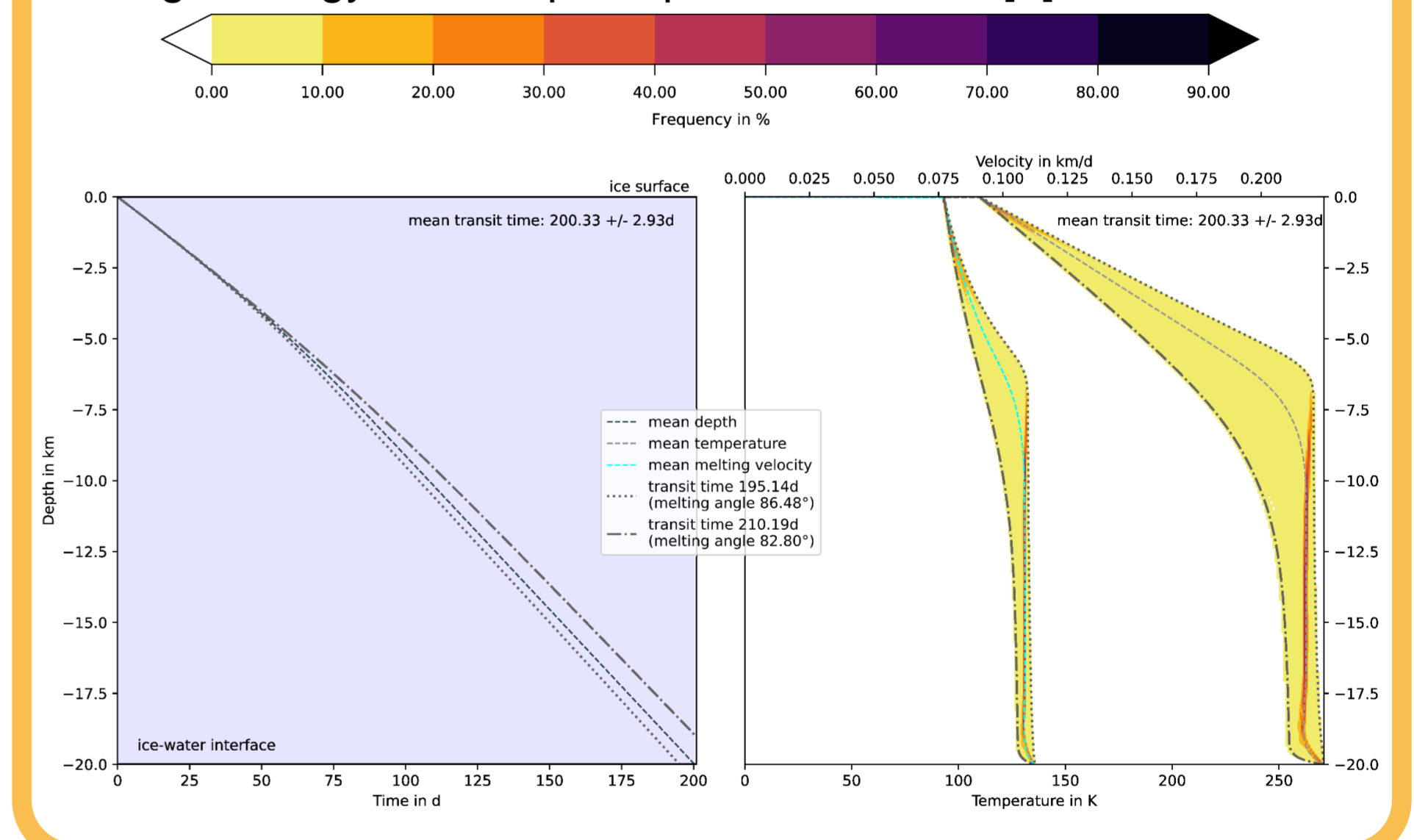
## Example: Ice Melting Probes



▲ Ice melting probes (here: EnEx-IceMole [2]) are useful tools to access subglacial water reservoirs on Earth and on other icy bodies in the Solar System. ◀ Geodynamic modelling results for Europa's ice shell provides us with temperature and density of the ice [3, 4].



▲ The forward motion of an ice melting probe is a complex multi-physics problem involving several processes [3]. ▼ Final trajectory simulations can provide mission relevant parameters as melting duration, total required energy and average energy consumption per meter of ice [4].

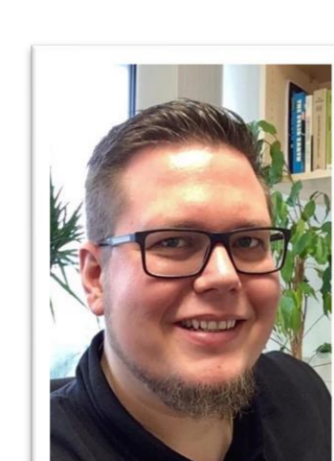


## Outlook

We are currently developing a more general Sim Data Hub that can be used for any kind of simulations and can occur in different instants (like the Ice Data Hub). Within this step we include, for example, GemPy ([www.gempy.org/](http://www.gempy.org/)) to view structural geological models in the GUI. The data crawler is reinvented by incorporating the Datamanagement-Toolkit LinkAhead from IndiScale ([www.indiscale.com/linkahead](http://www.indiscale.com/linkahead)). The Data Hub as functionally-enriched data platform shall be interfaceable with digital twin technology (e.g., for ice melting probes) in the future.



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## References

- [1] Simson et al. (2022), doi: 10.5281/ZENODO.7185422
- [2] Dachwald et al. (2014), doi: 10.3189/2014AoG65A004
- [3] Boxberg et al. (2021), doi: 10.5194/egusphere-egu21-13052
- [4] Boxberg et al. (2023), doi: 10.1089/ast.2021.0071



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