**EAS 4803/8803 Lab: Ice thermodynamics**

**NAME:**

If you are working in a group, please indicate the names of the students you are working with (groups of up to 3 students max are allowed):

**Alternative option**

Students can choose between completing this lab report or doing a summary of the publication of van Liefferinge et al. (2018) “*Promising Oldest Ice sites in East Antarctica based on thermodynamical modelling*”. Students opting for this option should do a summary of 2 to 4 pages of the publication. The summary can include figures, but these are not accounted for in the page count. The summary should be thorough, and should demonstrate that the student understood the methods, results, and conclusions from the study. Students are allowed to work in group (max 3 students per group) for the summary.

**Information**

**Due date: 28th of March 2023 11:59 pm**

Send your report or summary (depending on which option you choose) toVincent Verjans

**email:** vverjans3@gatech.edu

**Office:** 2116 in EAS

**Notes:**

1. I will confirm you that I received your lab report or summary (depending on which option you choose). If you do not receive my email of confirmation, that means that **I did not receive your report/summary**.
2. If you want to discuss some problems with me, I will be available during the following office hours:

Wednesday March 15 and Thursday March 16: 9:00 am-01:00 pm

Friday March 17: 9:00 am-12:00 pm

Tuesday March 21 and Friday March 24: 3:00 pm-5:00 pm

Monday March 27: 9:00 am-01:00 pm and 3:00 pm-5:00 pm

**Instructions for the lab report**

This lab is entirely based on the jupyer-notebook

modelTemperatureEvol.ipynb

at:

<https://github.com/wc2421/Glacier-and-Ice-Sheet-Dynamics-Labs> in the IceThermodynamics sub-directory.

To start with, read the Introduction carefully, and make sure to understand the objective of this lab. To run the notebook, you should have anaconda installed on your computer. In addition, you will need to install some basic libraries: numpy, matplotlib, netcdf4, scipy, and notebook. All the information to install anaconda is included in the section “Part 0: Information”.

To complete this report, you will need to type your answers in the empty spaces below the questions. Use the empty spaces also to include graphics where needed. The report includes **Questions 1 to 9**. The questions that count as a bonus are indicated as **Bonus**.

**Question 1** (10 points)

Analyze the time series of past surface temperatures at Summit Greenland.

(a) What is the mean temperature over the entire time series (125 000 years)? (3 points)

(b) What is the mean temperature over the last 11 700 years? (3 points)

(c) The last 11 700 years are known as the Holocene. This period is generally qualified as having a stable climate. Compare quantitatively the variability in temperatures during the Holocene and pre-Holocene. (4 points)

**Question 2** (20 points)

We first utilize Eq. (1) to model temperature evolution. This is a simplified version of the full 3-dimensional heat equation seen in class.

(a) Which processes are neglected in this form of the heat equation? (4 points)

(b) What are possible justifications to neglect them? (8 points)

(c) Provide a brief personal perspective on whether it is okay or not to neglect these processes. (8 points)

**Question 3** (20 points)

We use the parameterization of Huybrechts (1996) to estimate past snow accumulation rates as a function of past changes of temperature with respect to present-day (ΔT). Here, we use the present-day snow accumulation rate value bdot\_0 = 0.27 m w.e. / yr.

(a) Generate a graph showing bdot as a function of ΔT. (10 points)

(b) How do you interpret the relationship shown in (a)? What is the physical mechanism behind it? (10 points)

**Question 4** (10 points)

In the code, the variable wvel is the vertical ice velocity. It is calculated at each time step of the time iteration loop.

(a) Explain the formula that we use to calculate wvel. (5 points)

(b) We calculate the variable wvelstag from wvel. Why do we need wvelstag? (5 points)

**Question 5** (15 points)

What boundary conditions do we use at the top and base of the ice column.

(a) What is the name of these sorts of boundary conditions (i.e., their classification)? (5 points)

(b) Give the temperature equations in the finite-difference scheme for the temperature at the surface and at the base when applying the boundary conditions. (10 points)

**Question 6** (10 points)

From our first model run, we obtain a modeled temperature profile, which can be compared to the observed temperature profile from the GRIP core.

(a) Which of the assumptions could explain the discrepancies between the temperatures of the GRIP core and of the model results? Justify. (5 points)

(b) How do you interpret the small bulge at z =∼2900 m and z =∼2400 m? (5 points)

**Question 7** (15 points)

Quantify the performance of the model in reproducing the observations of the GRIP core. To do so, provide:

(a) the bias of the model (5 points)

(b) the root mean squared error (5 points)

(c) the coefficient of determination (5 points)

(d) **Bonus**: any other quantitative evaluation (+2 points)

**Bonus**: **Question 8** (+9 points)

Generate graphs of:

(a) how the ice specific heat capacity varies as a function of temperature (+3 points)

(b) how the ice thermal conductivity varies as a function of temperature (+3 points)

(c) how the ice flow parameter varies as a function of temperature (+3 points)

In addition, provide a brief description of these three graphs.

**Bonus**: **Question 9** (+10 points)

We use the Robin solution to initialize the temperature profile. To compute the Robin solution, we use our estimates of the surface temperature and snow accumulation rate of 125 000 years ago.

(a) Change the surface temperature and snow accumulation rate used to calculate the initial Robin solution. Run the model again. How much does the modification in the Robin solution affect the final (i.e., present-day) ice temperature profile from the model? (+5 points)

(b) Think about your results in (a). How can you explain your observations? (+5 points)