Thermal response of the Greenland Ice Sheet through the last Ice Age to Present

Kolumban Hutter, Reinhard Calov

Institut für Mechanik, Technische Hochschule
Hochschulstr. 1, D-W-6100 Darmstadt, Germany

Modelling the flow of ice is such a complex problem that it is reasonable to focus interest on one single effect and neglect other processes in order to understand the principles underlying that effect. In this work we consider the evolution of the temperature distribution, and in particular, the evolution of the basal temperature of the Greenland Ice Sheet through time by neglecting the change in ice thickness. Our aim is to understand the principles of the atmospheric temperature variation through the Ice Age(s) on the Greenland Ice Sheet. Obviously, since according to ice core date "Dye 3" and "Camp Century" were ice free during the Eemian Interglacial, our computations are likely to deliver somewhat higher basal temperatures with inferences or the safe side for temperate patchiness. Computations are being performed for a finite difference model of the well known shallow ice equations (1). The present surface temperature distribution is a mathematical fit to the data of Ohmura (2). Its temporal evolution follows modified time series of the Vostok data (3), *fig. 1*. Scenarios I and II are approximate upper and lower bounds, respectively to this temperature driving, prolonged into the past by one period to let the model swing into the proper initial temperature distribution 145 kyrs BP. The geothermal heat flow is chosen to be 42×10^{-3} Wm^{-2} either prescribed at the ice rock interface (scenarios are then called I and II, respectively), or 4 km below in a rigid, but thermally responding rock bed (in which case scenarios are called I-S and II-S, respectively). Computations are also performed for hard holocene ice (with enhancement factor E = 1) and softer pleistocence ice with E = 3).

Results show the following typical qualities:

- Because of the considerable thermal inertia of the rock bed, the temperature distribution of the Greenland Ice Sheet may contain some remnants of the Illinoian Ice Age.

- Its base has always had temperate (hot) patches, the size of which varied through time, see *Table 1* but the bore hole sites "Dye 3", "Camp Century" and "Summit" have always been cold.

- The basal temperature and the areal coverage of the base with temperate patches depends considerably on the thermal inertia of the rock bed. *Fig. 2* shows present homologous temperatures at the bed for scenario I - S.

A detailed report on this will appear in Refs. (4), (5), (6)

Table 1: Comparision of scenarios. Present temperate patches of the base of the Greenland Ice Sheet for various scenarios.

Scenario	E	A' x 10^3 km^2	$\frac{A'}{A}$ x 100
Steady	1	208.0	12.0 %
Steady	3	35.4	2,0 %
I (or II)	1	100.0	6,0 %
I-S	1	60.0	3,5 %
I-S	3	11.2	0,7 %

References:

1. K. Hutter, *Theroretical glaciology; material science of ice and the mechanics of glaciers and ice sheets*. D. Reidel, Dortrecht, 1983
2. A. Ohmura, *Zeitschrift für Gletscherkunde und Glazialgeologie, **13***, (1987)
3. J. M. Barnola, D. Raynaud, Y. S. Korotkevich, C. Lorius, *Nature, **329***, 408 (1987)
4. R. Calov, K. Hutter, 1993 pending publication
5. R. Calov, 1993 pending dissertations
6. R. Calov, K. Hutter, 1993 DFG-Fortsetzungsantrag

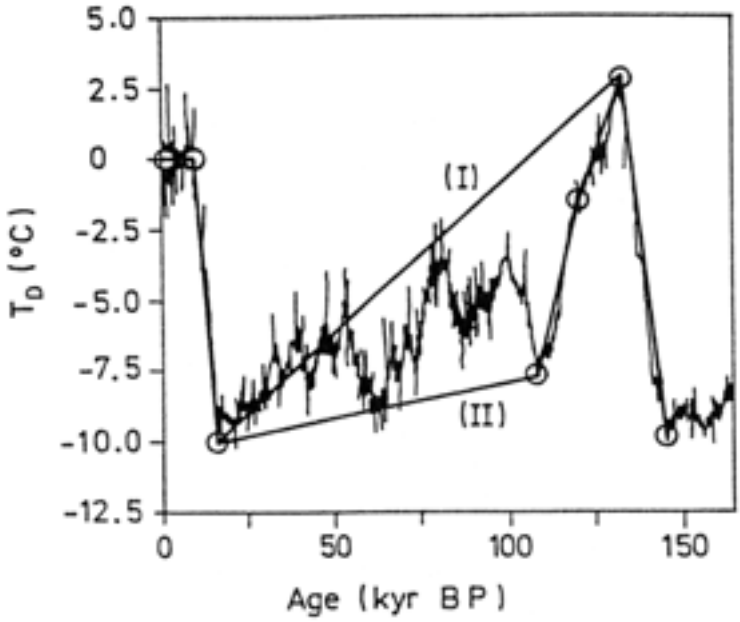

Figure 1: Surface driving temperature as inferred from the Vostok data and upper (I) and lower (II) bounds to these data. The ice age cycles I and II are continued back to 274 kyrs BP, to "swing-in" the computational model.

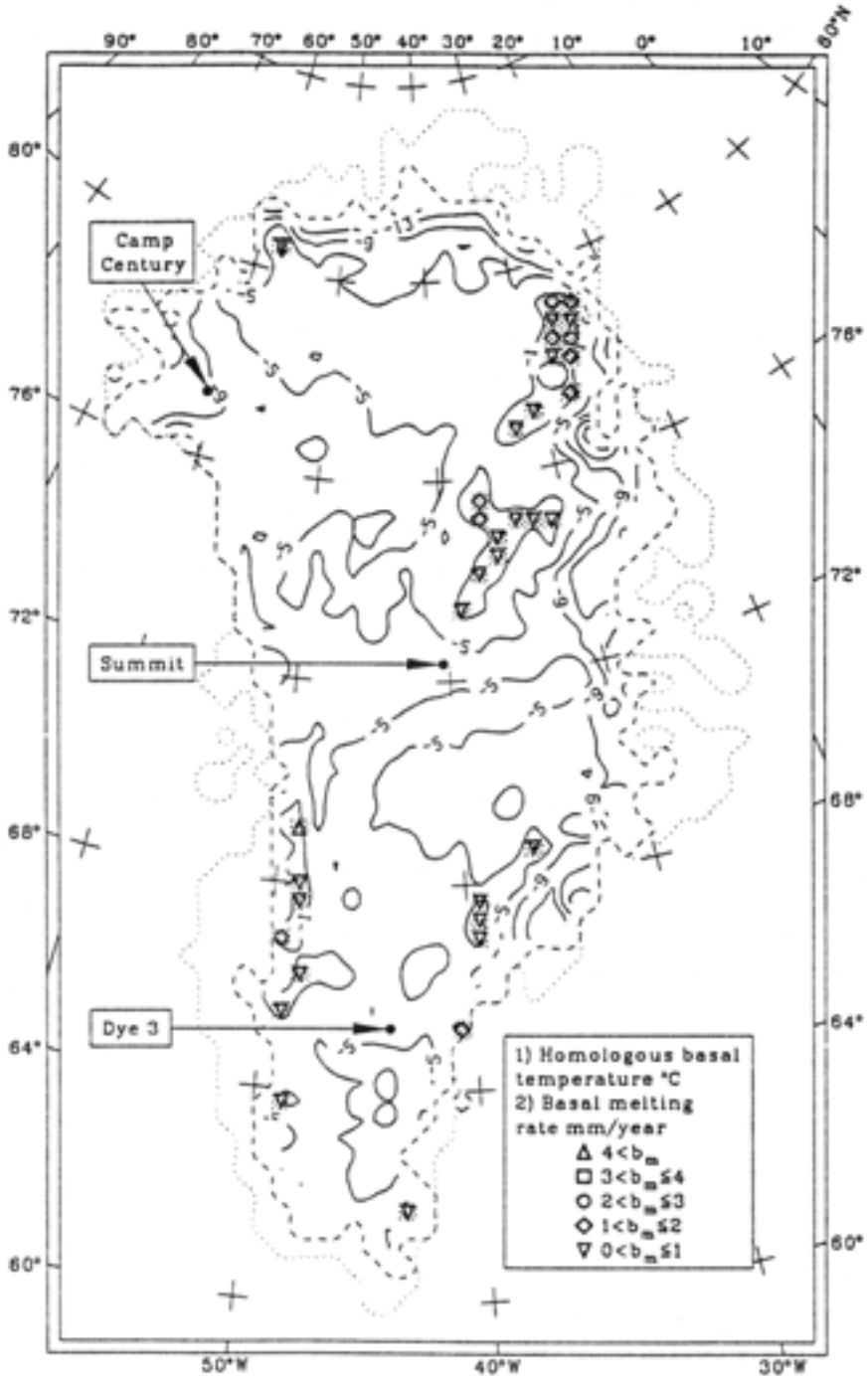

Figure 2: Today's computed homologous basal temperatures of the Greenland Ice Sheet for scenario I-S and E=1. Homologous isotherms are shown for T_B' = - 1, - 5, - 9, ...° C and regions with temperate basal ice are shaded. Symbols indicate the annual basal melting rate in intervals shown in the inset.