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The ISMIP HEINO project: Intercomparison of large-scale oscillations in ice-sheet models

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Heinrich Events - Motivation

IRD discovered in marine cores

QUATERNARY RESEARCH 29, 142–152 (1988)

Origin and Consequences of Cyclic Ice Rafting in the Northeast Atlantic Ocean during the Past 130,000 Years

HARTMUT HEINRICH

Deutsches Hydrographisches Institut, Bernhard-Nocht-Str. 78, D-2000 Hamburg 4, West Germany

Received April 7, 1987

The main source of IRD is the Laurentide ice sheet

Climate Dynamics (1992) 6:265–273

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Origin of the northern Atlantic's Heinrich events*

Wallace Broecker, Gerard Bond, Mieczyslawa Klas, Elizabeth Clark, and Jerry McManus

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Received March 7, 1991/Accepted April 12, 1991

Abstract. As first noted by Heinrich, 1988, glacial age sediments in the eastern part of the northern Atlantic contain layers with unusually high ratios of ice-rafted lithic fragments to foraminifera shells. He estimated the depth separation between the stage 1–2 and stage 4–5 boundaries require an average sedimentation rate of about 6 cm/10^3 years for this interval. Thus, our samples are spaced at about 150 year intervals. We ex-

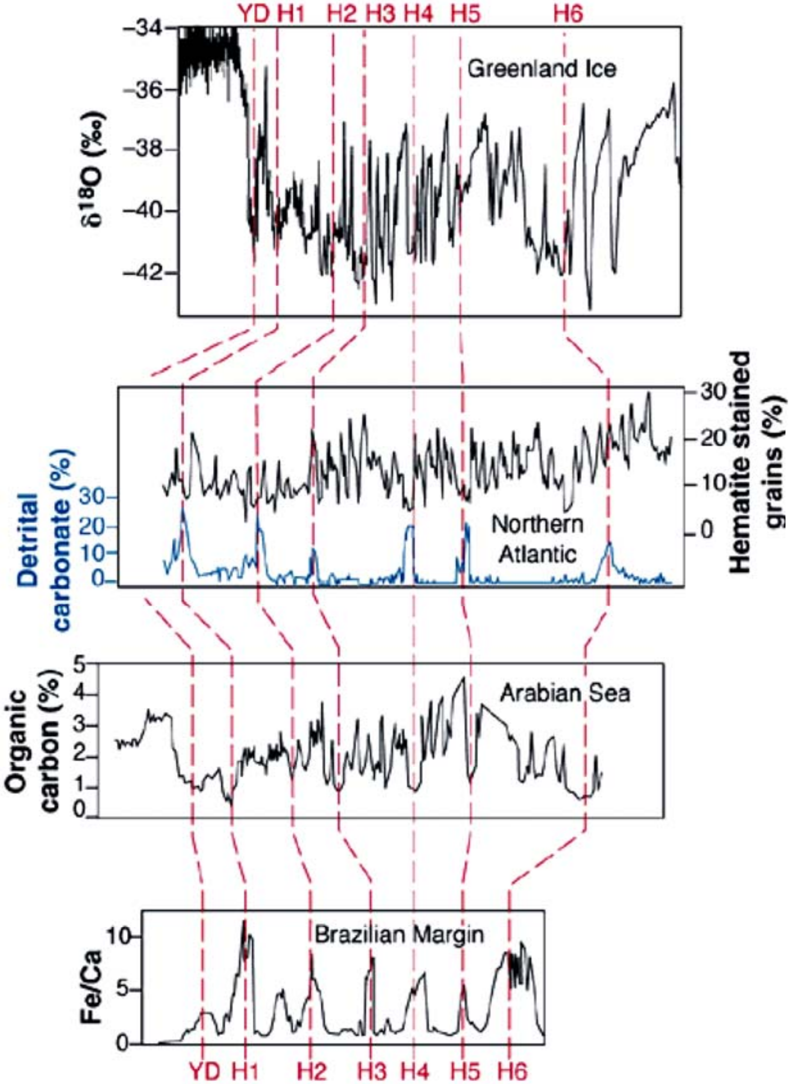
Heinrich Events - Motivation

250 μm

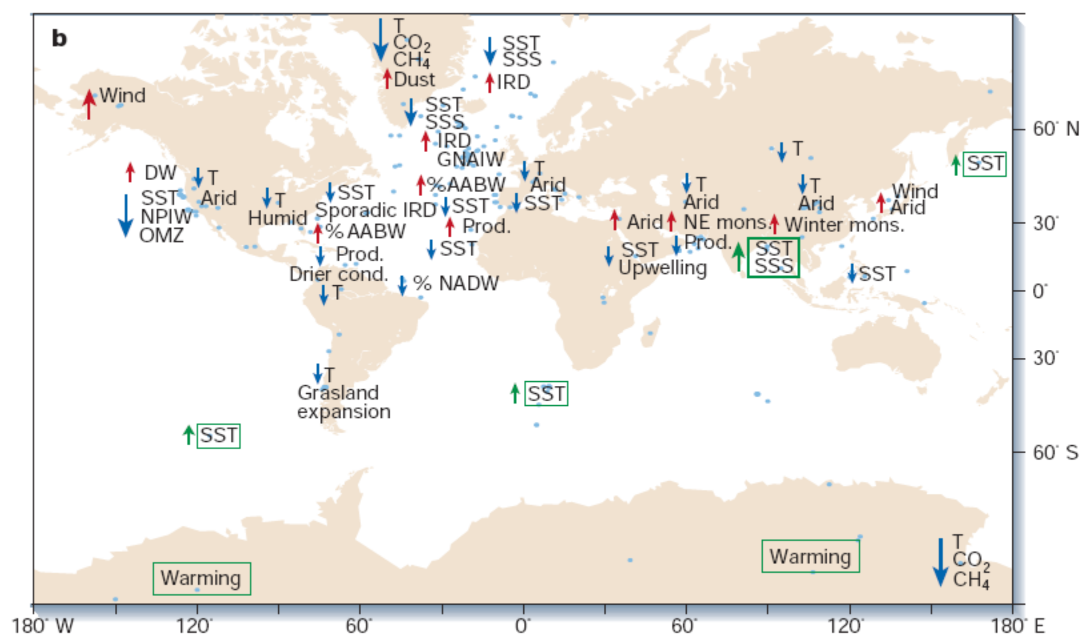
Glacial North Atlantic sediment

Heinrich layer sediment

Heinrich Events - Motivation

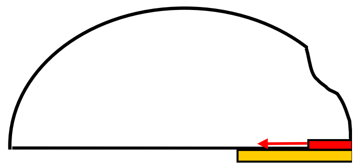


Heinrich events have a global impact on climate

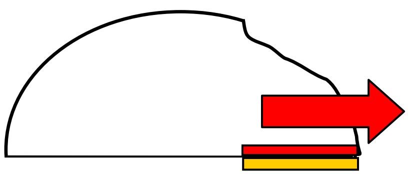


The mechanism of a Heinrich cycle

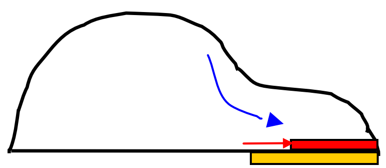
1. Activation phase



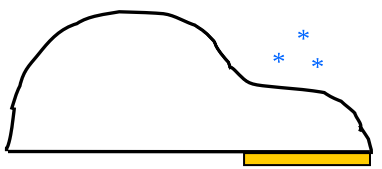
2. Surging phase



3. Deactivation phase

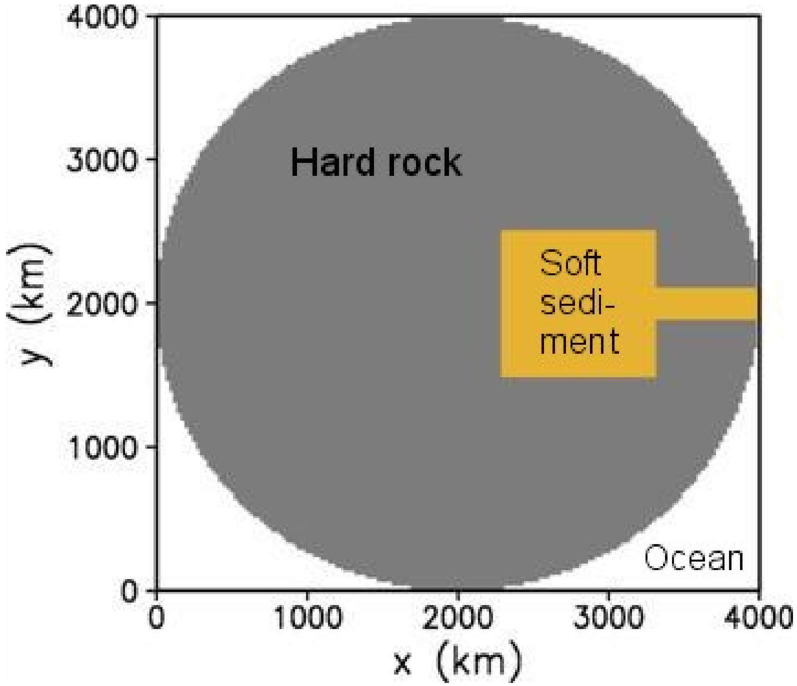


4. Recovering phase



Model setup

➢Model Domain



➢Sliding

$$\boldsymbol{v}_\mathrm{b} = \begin{cases} -C_\mathrm{R} H \, |\boldsymbol{\nabla}_\mathrm{H} h|^2 \, \boldsymbol{\nabla}_\mathrm{H} h & \text{for } T_\mathrm{b} = T_\mathrm{pmp} \text{ and hard rock,} \\ -C_\mathrm{S} H \boldsymbol{\nabla}_\mathrm{H} h & \text{for } T_\mathrm{b} = T_\mathrm{pmp} \text{ and soft sediment,} \\ \mathbf{0} & \text{for } T_\mathrm{b} < T_\mathrm{pmp}, \end{cases}$$

$$C_\mathrm{R} = 10^5 \, \mathrm{a}^{-1}, \qquad C_\mathrm{S} = 750 \, \mathrm{a}^{-1}$$

Model setup

➢Atmospheric boundary conditions

Surface temperature

$$T_\mathrm{s} = T_\mathrm{min} + S_T d^3$$

$$T_\mathrm{min} = 233.15\,\mathrm{K}, \quad S_T = 2.5 \times 10^{-18}\,\mathrm{K\,m^{-3}}$$

Surface mass balance

$$b = b_\mathrm{min} + \frac{b_\mathrm{max} - b_\mathrm{min}}{R} \times d$$

$$b_\mathrm{min} = 0.15 \text{ m ice equiv. a}^{-1}, \quad b_\mathrm{max} = 0.3 \text{ m ice equiv. a}^{-1}$$
$$d = \text{ distance from the center of the domain}$$

Simulations

Iteration Time: 200,000 years, Inspected: last 50,000 years

Run ST

Parameters as above

Runs T1 and T2

Surface temperature: T_s-10 and T_s+10

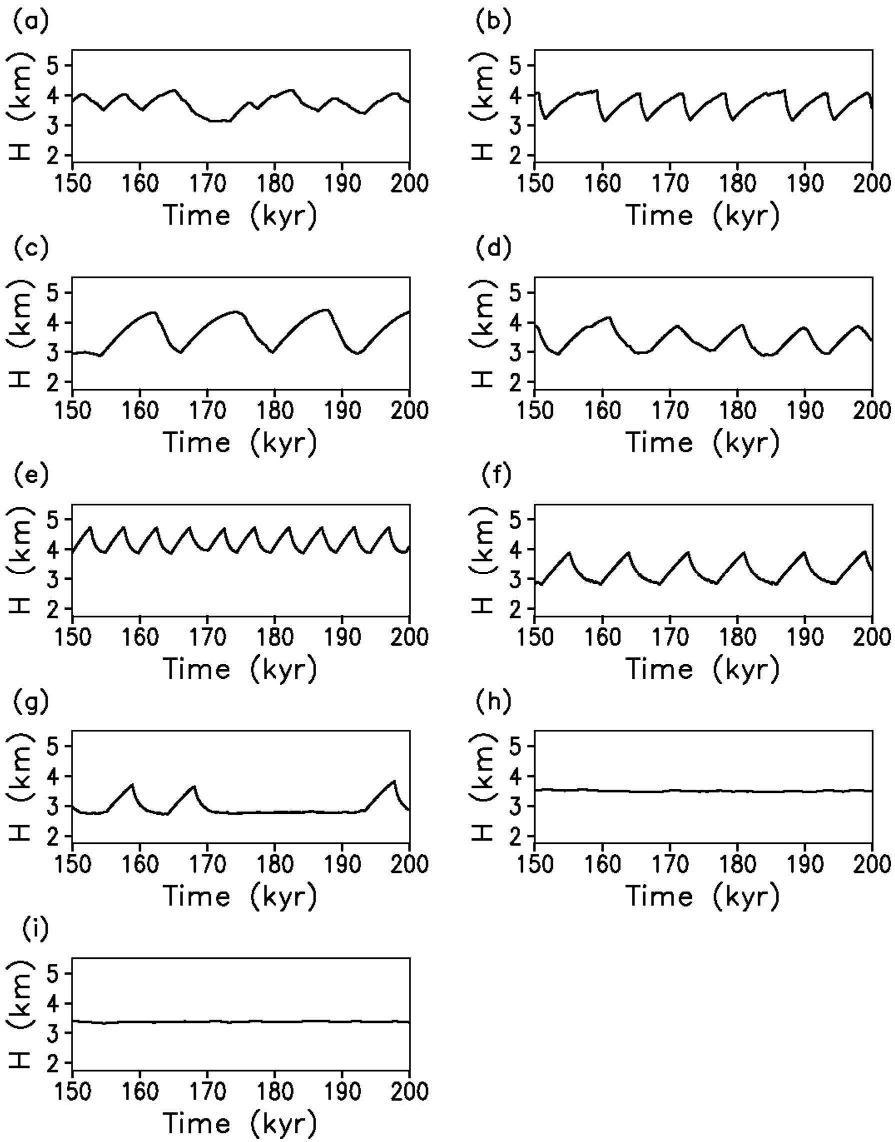
Runs B1 and B2

Surface mass balance: $b \times 1/2$ and $b \times 2$

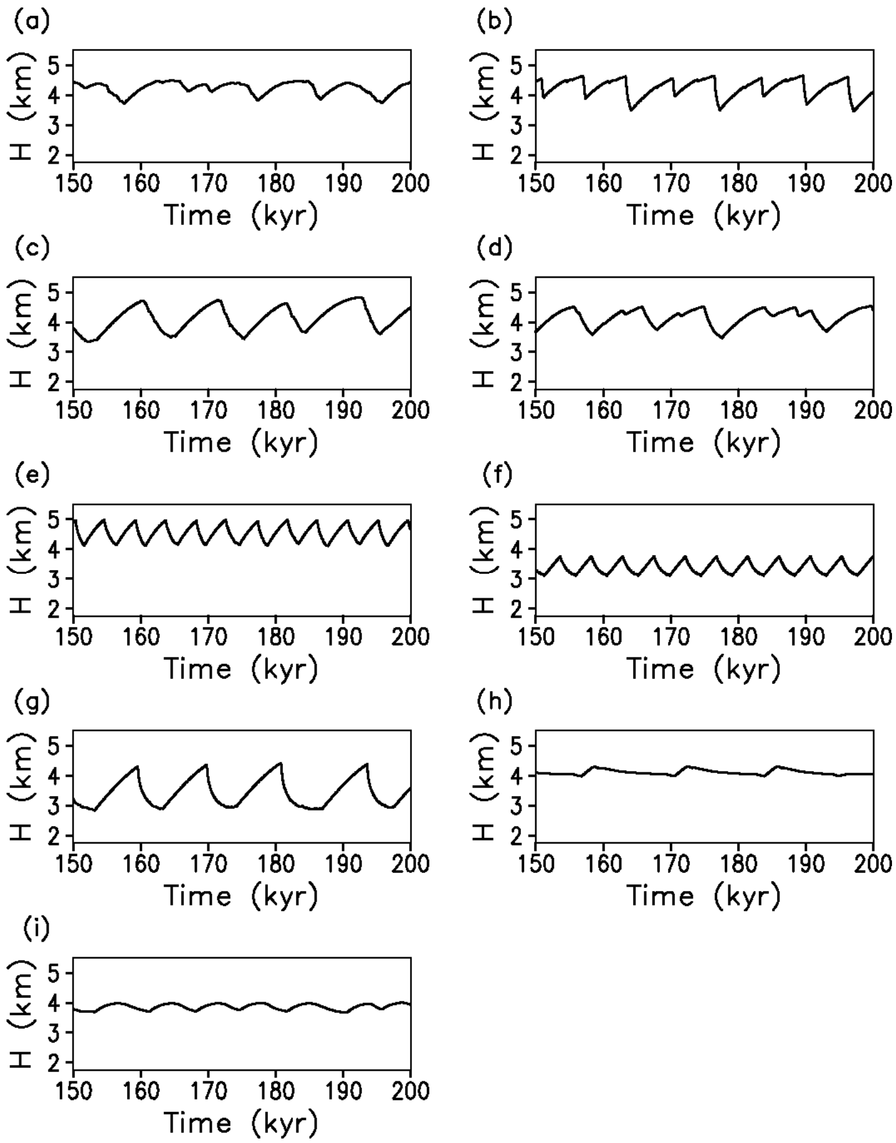
Runs S1, S2 and S3

Sediment sliding parameter: $C_s \times 1/5$, $C_s \times 2/5$ and $C_s \times 2$

Average Ice Thickness over Sediment in Run ST

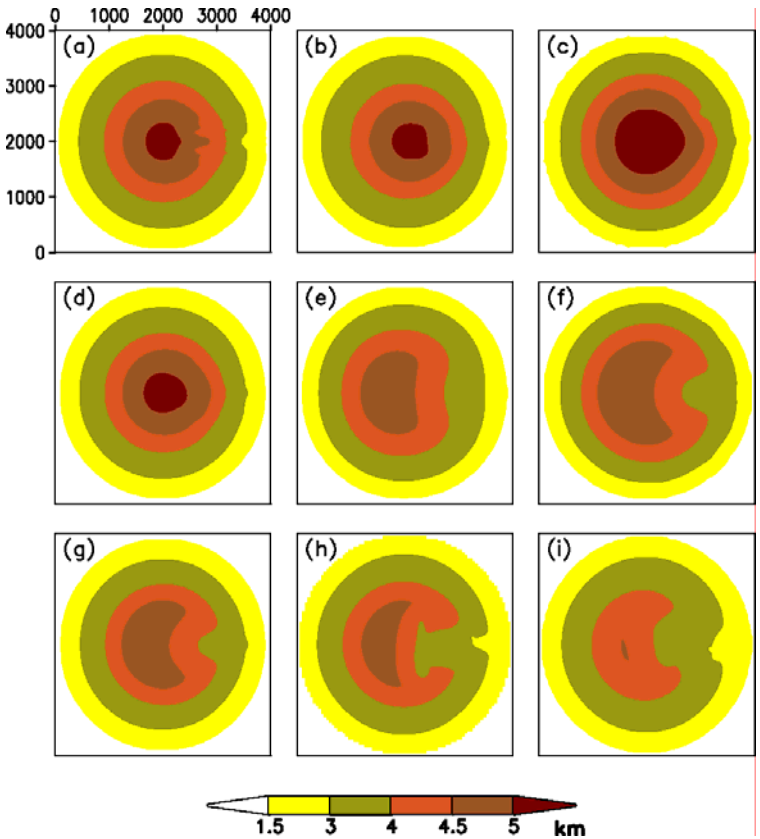


Average Ice Thickness over Sediment in Run T1

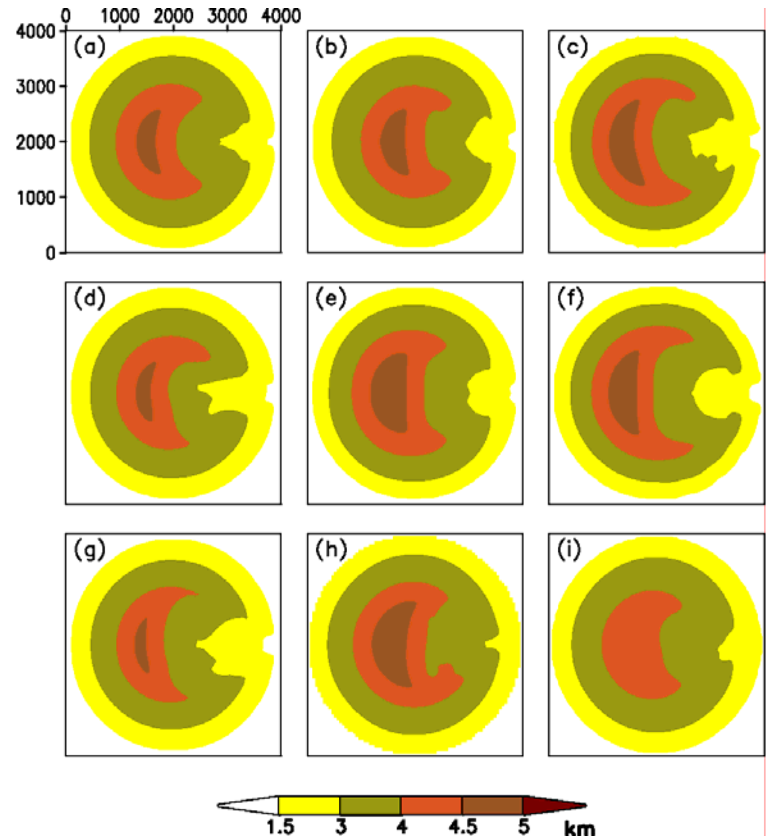


Surface Elevation in Run ST

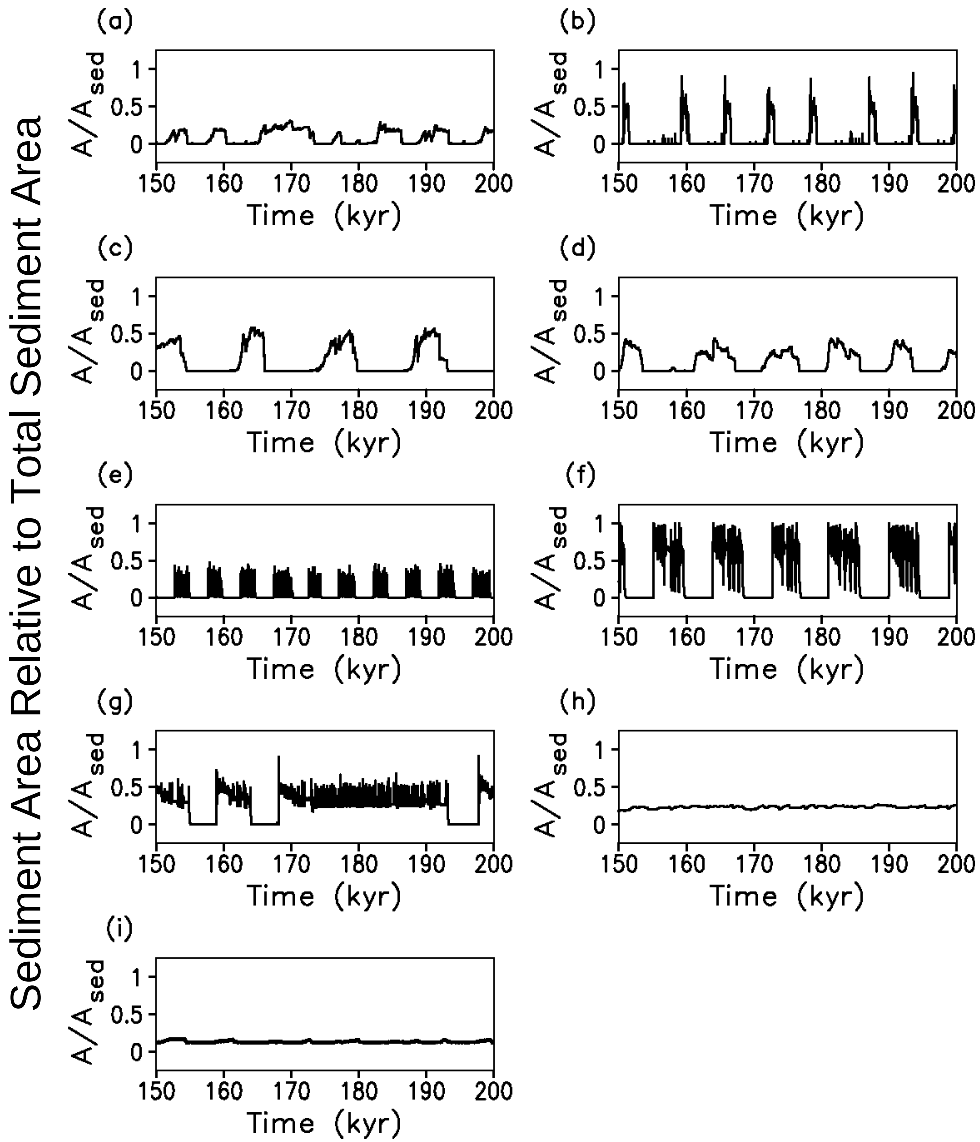
Maximum



Minimum

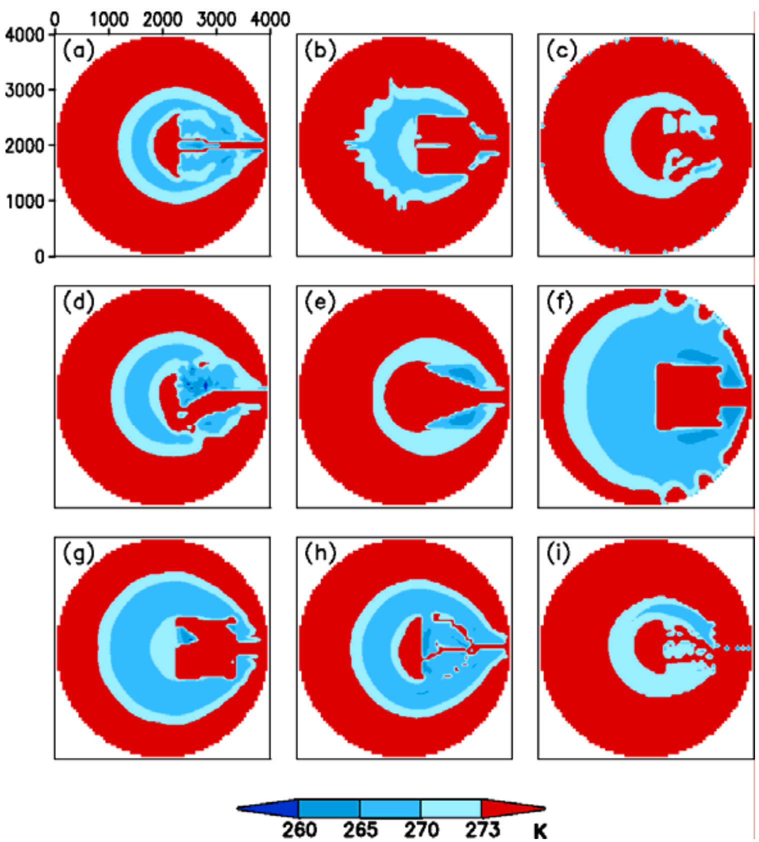


Relative Temperate Basal Area over Sediment in Run ST

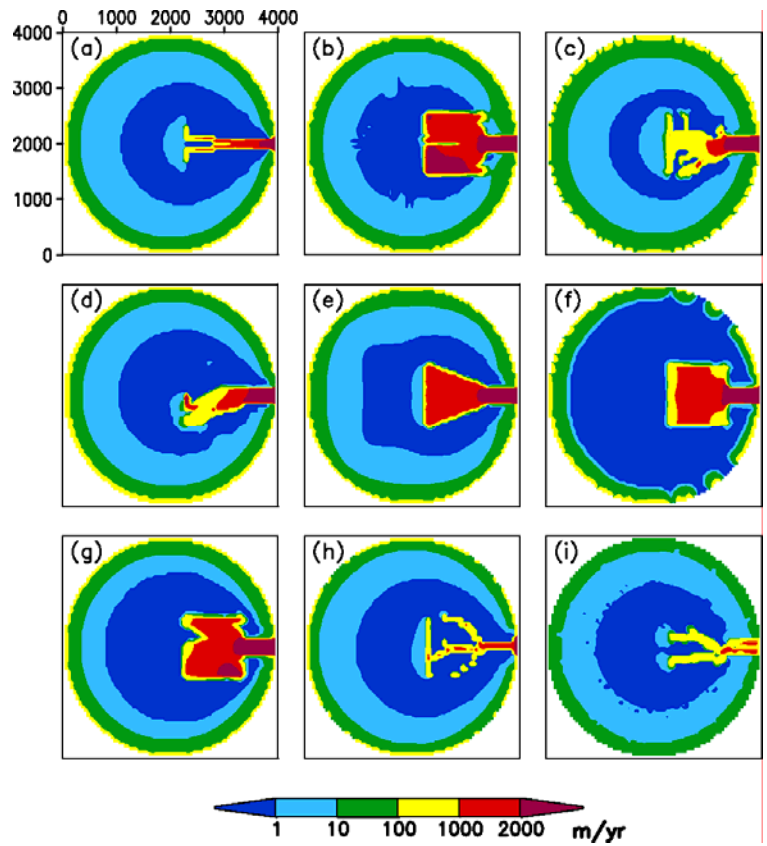


2D Basal Fields when Temperate Basal Area is Maximal in Run ST

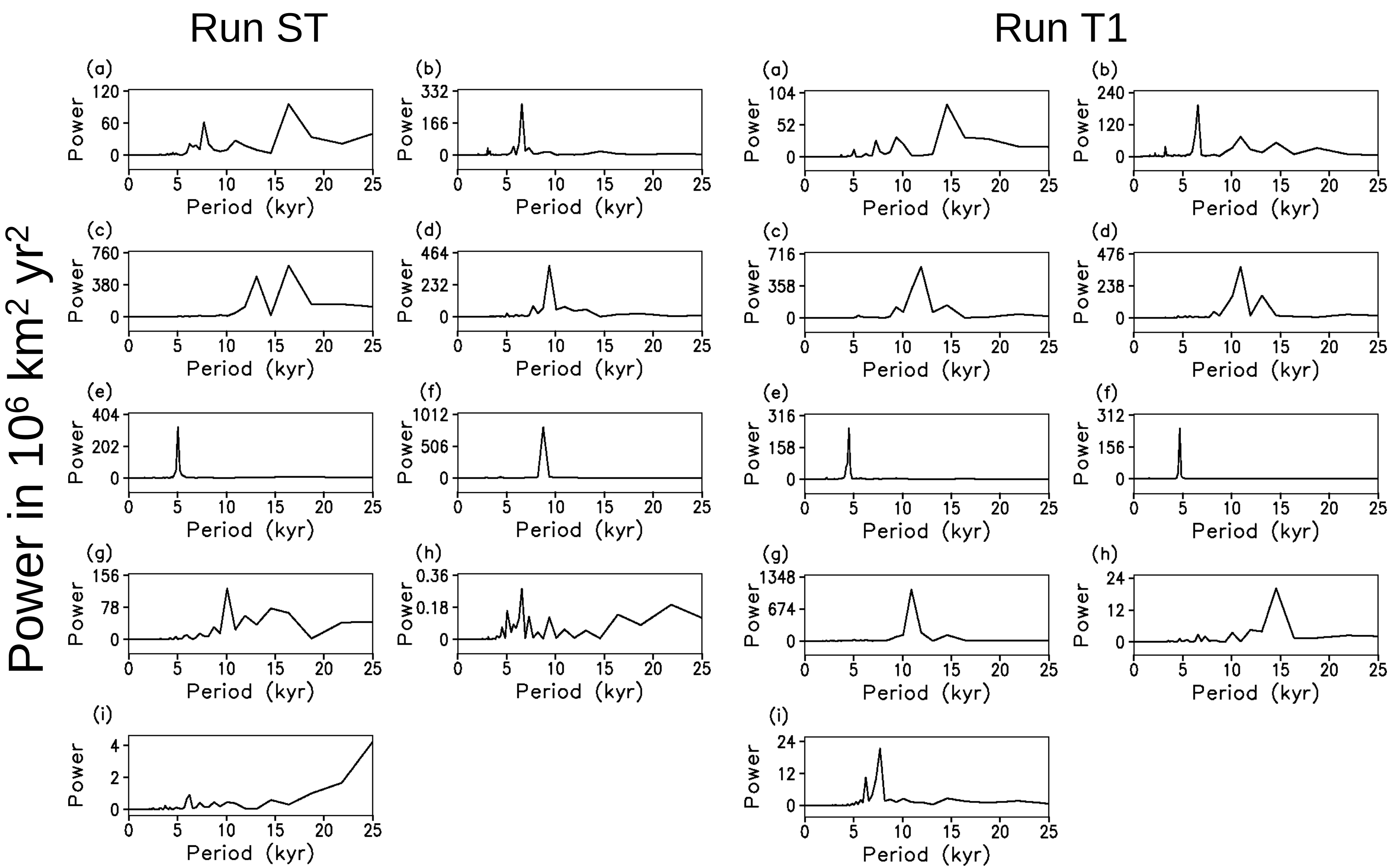
Basal Temperature Relative to Pressure Melting



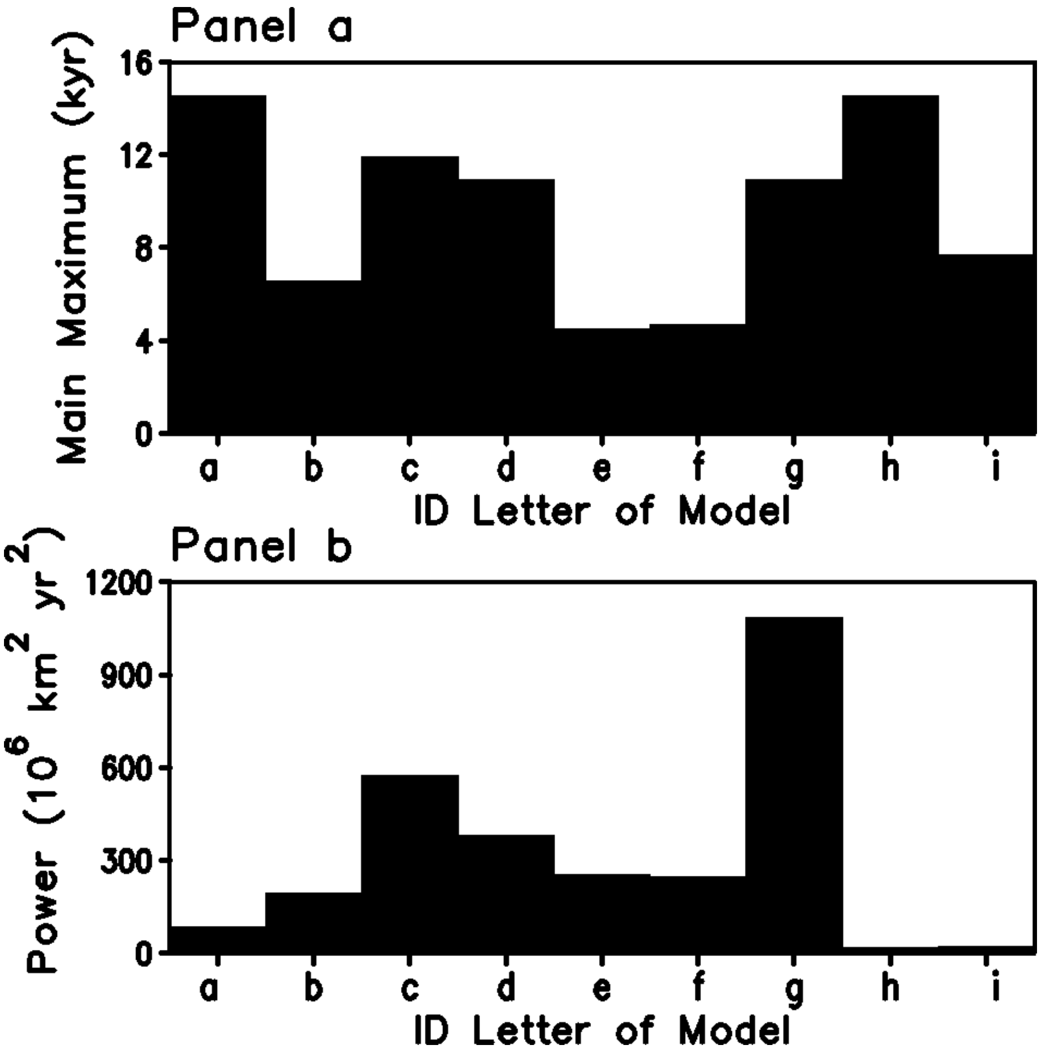
Sliding Velocity



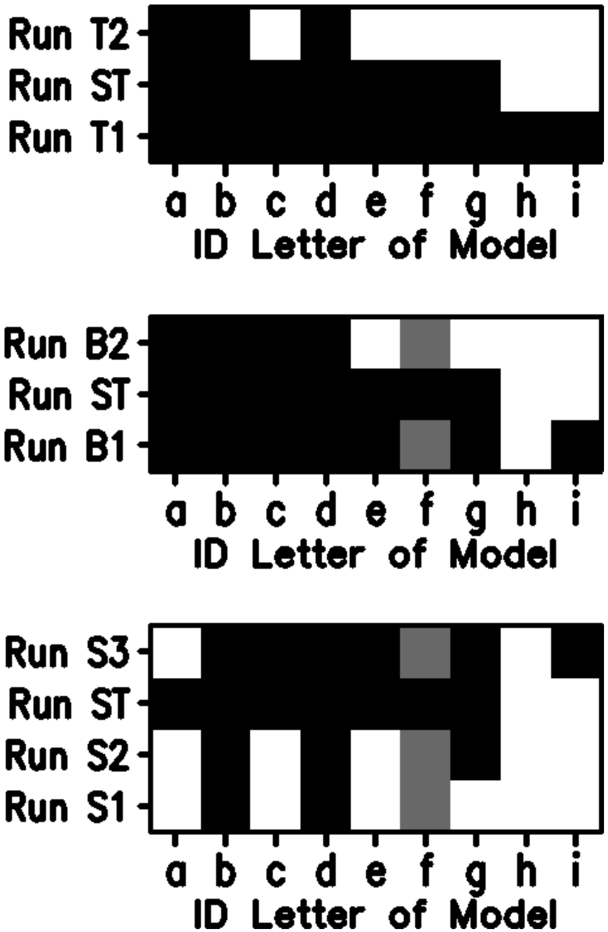
Power Spectra of the Average Ice Thickness over Sediment



Period and Power of Main Maximum for the Spectra of the Average Ice Thickness over Sediment in Run T1



Parameter Space



- there are oscillations (criterion: period 5 to 20 kyr, power > 10^7 km^2 yr^2 and distinct peak visible in power spectrum)
- no oscillations
- no data

Conclusions

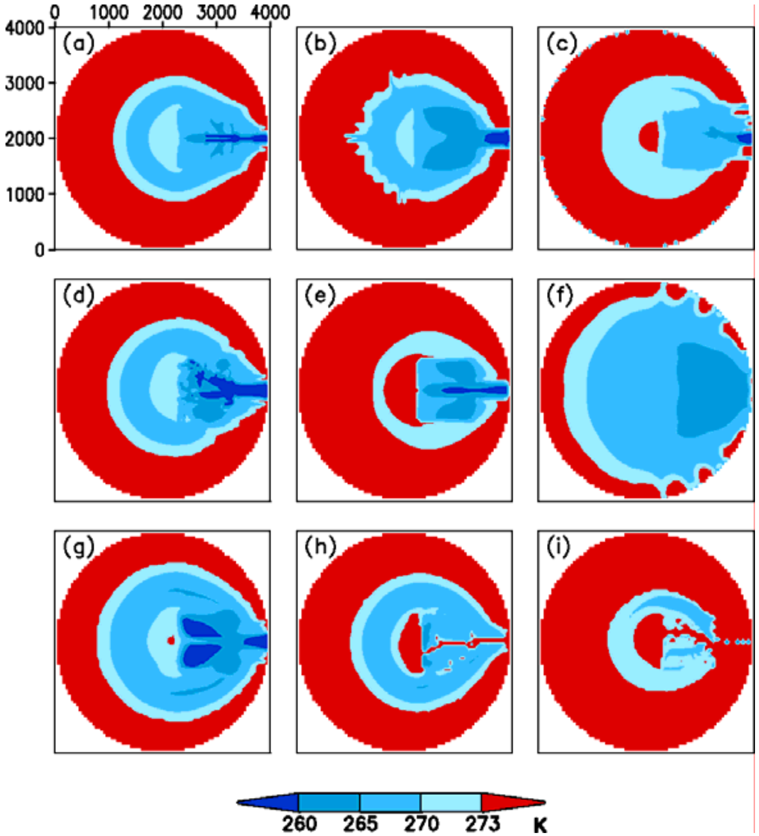
- 9 model are inspected
- 7 models have strong oscillations
- All models have an activation wave
- The period of the oscillations is in the order of thousands of years
- Although there are oscillations for a broad range in parameter space, they disappear for a number of models if the surface temperature is too high, the snowfall is too strong and the sliding parameter is too low
- In general, models need to be improved to properly reproduce all phases of a Heinrich cycle

Outlook

- Paper we will be submitted in 2009

2D Basal Fields when Average Basal Temperature is Minimal in Run ST

Basal Temperature Relative to Pressure Melting



Sliding Velocity