Large-scale ice-sheet oscillations - mechanism, modelling, intercomparison

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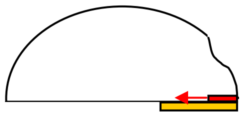
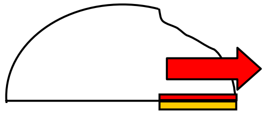
Mechanism of a HE cycle

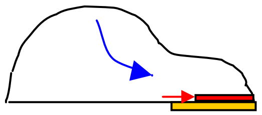
Activation phase. If the ice sheet is sufficiently thick an upstream migration of temperate basal area starts (activation wave).



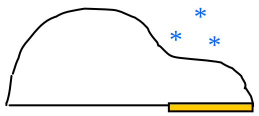
Surging phase. High sliding velocity over water saturated sediment decreases the ice thickness over the sediment area.



Deactivation phase.
If advection of cold ice prevails the basal frictional heating a deactivation wave terminates the surge.

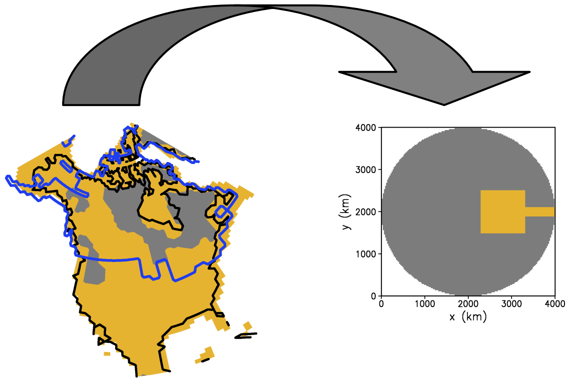


Recovering phase.
Snowfall rebuilds the ice sheet until the cycle can start again.



The ISMIP-HEINO project

We propose the intercomparison project ISMIP HEINO (Heinrich Event INtercOmparison; http://www.pik-potsdam.de/~calov/heino.html) using simplified ice sheet geometry and boundary conditions. Because thermal properties are an important issue to model HE cycles, our intercomparison project is addressed to thermomechanical ice sheet models. In order to focus on the relevant mechanisms, the shape of the continent and the area of sediment are prescribed in our setup.



The model domain is assumed as a circular continent with a diameter of 4000 km surrounded by ocean. On the continent, we differ between hard rock (grey) and soft sediment (dark yellow). The horizontal resolution is 50 km.

Basal Sliding

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

$$C_{\rm R} = 10^5\,{\rm a}^{-1}, \quad C_{\rm S} = 500\,{\rm a}^{-1}$$

Surface Accumulation

$$b = b_{\rm min} + \frac{b_{\rm max} - b_{\rm min}}{R} \times d, \qquad R = 2000\,{\rm km}$$

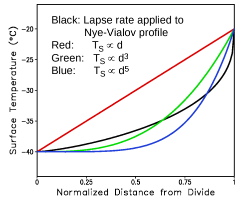
$$b_{\rm min} = 0.15 \text{ m ice equiv. a}^{-1}, \quad b_{\rm max} = 0.3 \text{ m ice equiv. a}^{-1}$$

$d =$ distance from the center of the domain

Surface Temperature

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

$$T_{\rm min} = 233.15\,{\rm K}, \qquad S_T = 2.5 \times 10^{-9}\,{\rm K\,km}^{-3}$$



Model Runs

The model runs are carried out over 200,000 years. Time slices at particular points in time and time series over the last 50,000 years of the simulation are proposed as output for comparison and investigation. In addition to the standard run, simulations with different parameter values for the surface temperature (T_{min} changed by ±10°C), the surface accumulation (b_{min} and b_{max} both are varied by the same factor of 0.5 and 2, respectively) and the sediment sliding (C_S=100, 200, 1000 a^{-1}) in order to trace the parameter space of the given model are proposed. Details are specified in ISMIP-HEINO setup description.

Research Questions

- Are there self-sustained oscillations in the given ice-sheet model, and under which circumstances do they appear?
- How long does a surge event last and how long is the recurrence time between events? Are the events periodical or quasi-periodical?
- How large are the changes in ice volume, ice thickness, homologous basal temperature and basal temperate area?
- How do the ice-surface elevation, homologous basal temperature, sliding and surface velocity look like at certain time slices before, during and after the events?