EISMINT INTERCOMPARISON EXPERIMENT

COMPARISON OF EXISTING GREENLAND MODELS

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INTRODUCTION

The objective is to compare the different existing models when they are applied to a real ice sheet. There is a glaciological interest to see how the different models perform in real cases. Another purpose more linked to climate studies is to estimate the validity of the reconstructions the models can produce. The time scale of these reconstructions is either the last climatic cycle or the close future to investigate the effect of a global warming.

Compared to the schematic ice sheet used in the previous EISMINT intercomparison experiments, the Greenland ice sheet adds two important features :
- The bedrock is rough
- There is a mass balance-surface elevation feedback.

Moreover it is possible to compare the results with the present surface topography extension, surface slope, shape of contour lines.

TYPE OF MODELS

The models concerned by this intercomparison are those simulating the evolution with time of the ice sheet geometry and of the temperature and velocity fields within the ice. As there are now several 3D models with thermomechanical coupling we will focus on this type of model. However, models without thermomechanical coupling (vertically integrated) can also participate to the intercomparison.

The isostatic response should be modelled also, and the method chosen should be described. If the unloaded bedrock is necessary, we will assume that the present bedrock is in equilibrium with the present ice sheet (although this is not absolutely true).

Participants should provide information on their model in the file INFO.name (see result files)

EXPERIMENTS

We plan to compare the models for three simulations :

1) Steady state with present climatic conditions

The initial condition is given by the present surface and bedrock topography. The time needed to reach the equilibrium depends on the initial temperature field and on the models. For this steady state simulation it is better not to include the thermal conduction in the bedrock because it makes the equilibrium time longer. The simulation is stopped when the criterium of steady state is fulfilled. This criterium is a change in volume less than 0.01% in 10000 years. The simulated time necessary to reach such a steady state must be mentionned.

2) Evolution along the last climatic cycle

The initial ice sheet is the one obtained with the steady state simulation.

The forcing in temperature is derived from the GRIP ice core (Dansgard and al. 1993, see INPUT FILES). This ice core is supposed to go back to 250 000 years BP but it is now accepted that the deeper part of the ice core was affected by ice flow processes so it is not reliable for periods older than the previous interglacial. However it is a better representation of the temperature before the Eemian than a steady state. The temperature field at 130 000 years BP should then be more realistic. Consequently the simulation covers the last 250 kyr but the results will be significant only for the period 130 kyr to present. The models will be compared only on this period.

The temperature changes at GRIP can be derived from the $\delta^{18}O$ content,
$\Delta T = 1.5 (\delta\ ^{18}O + 35.27)$

The GRIP file (sum89-92-ss09-50yr.stp) contains the 50 years averages of original series. It was provided by Sigfus Johnsen. The time scale ss09 is only slightly different from the ss08 that is on the server of the noaa (see input files). The isostopic record is the one used for the temperature calculations in Johnsen et al. (1995). The value -35.27 ‰ is the average for the last 50 years. We suppose that over these 50 years the temperature is the same as today. The ages are years before 1989.

Note that the temperature at GRIP is the result of the climatic processes and is not really a forcing. We propose this record to force the models because it is an easy method when using the degree day method as most models do. Some models may use a different method (EBM for example). Provided they can reconstruct the same temperature (or close) at GRIP they can participate to the intercomparison. People can also choose if the climatic forcing is spatially constant or changes for example with latitude and altitude.

The sea level change is derived from the SPECMAP curve (Imbrie et al. 1984, see INPUT FILES).
ΔSea level = -34.83 ($\delta^{18}O$ +1.93)

In order to compare the greenhouse experiment with a "standard" experiment the time integration of the climatic cycle run should be carried on for the next 500 years in the future with $\Delta T = 0$ and Δsea level = 0.

3) Greenhouse warming.

The initial ice sheet is the one obtained for the present (1989) in the climatic cycle simulation. The simulation covers 500 years.

Temperature forcing: There are many projections of future climate but they often cover only one century. We choose to prescribe a scenario similar to the result of Manabe and Stouffer (1994) in the case of 2 x CO_2 (stabilisation simulations). This scenario covers 500 years and we depict it with two warming rates: Between 0 (start of the simulation) and 80 years, the temperature increases with the rate 0.035 °C/year (2.8 °C for 80 years). Between 80 and 500 years, the warming rate is 0.0017 °C/year (.714 °C for 420 years). The total temperature increase is 3.514 °C.

Sea level forcing: No change.

PARAMETERS

We consider two levels
Level 2: with a prescribed set of parameters
Level 3: with the preferred set of parameters for each model

The steady state experiment has to be performed twice with level 2 and level 3. The purpose of level 2 is to compare the models with exactly the same set of parameters and try to estimate the relative influence of the parameters and of the models themselves. The prescribed set of parameters is given in Table 1. If possible, for this level, ablation rate should be calculated with a degree day method.

TOPOGRAPHICAL AND METEOROLOGICAL DATA

Bedrock and surface (present) topography are those compiled by Anne Letréguilly (Letréguilly et al. 1991) on either a 20 km or 40 km grid in polar stereographic projection. For the surface elevation, the data set compiled by Ekholm (Ekholm and al. 1995) is more accurate, however there is no bedrock topography on the same grid . We thus prefered to use the Letréguilly's grid file that has already been used by several modelling groups (see

also INPUT FILES).

Ellesmere Islan d. The surface and bedrock data set is not good on Ellesmere Island. This has no consequence for the steady state and the greenhouse simulations. For the climatic cycle simulation it is likely that the greenland and Ellesmere ice sheets merge when the sea level drop while there is almost no ablation. We want to focus on the Greenland ice sheet so we would like each modeller to prevent his Greenland ice sheet to merge with the Ellesmere one.

Some models are not in Cartesian plane grid but in latitude longitude one. In the grid files the latitude and longitude of each node are given so it is possible to reconstruct a new grid. People wanting to run their model in spherical coordinate should contact Catherine Ritz in order to find the best way to compare with the plane experiments. The participants using the cartesian grid do not have to include map-distorsion factors to account for the projection.

Precipitation rates were compiled by Philippe Huybrechts from Ohmura and Reeh (1991), and are on the same grid as topography. WARNING : this map is already converted in ice equivalent (with density 910 kg m^{-3}).

Data of the surface temperature were compiled by Ohmura (Ohmura 1987) but are not on a grid. The following parameterisation gives a good fit to these data (Huybrechts and al. 1991)

Mean annual temperature **Ta** (in deg C)
Ta = 49.13 - 0.007992 * Z -0.7576 * latitude

where Z=max (Surface elevation, 20*(latitude-65))

Summer temperature **Ts**
Ts = 30.78 -0.006277 * (surface elevation) - 0.3262 * latitude

SUMMARY ON THE EXPERIMENTS

There are 4 experiments

The experiment names are :
SSL2 Steady state , prescribed set of parameters (table 1)
SSL3 Steady state , free set of parameters
CCL3 Climatic cycle simulation (free set of parameters)
GWL3 Greenhouse warming simulation (free set of parameters).

Table 1 Prescribed set of parameter for level 2

gravity	9.81 m s^{-2}
gas constant	8.314 J mol^{-1} K^{-1}
ice density	910 kg m^{-3}
mantle density	3300 kg m^{-3}
sea water density	1028 kg m^{-3}

Deformation law. Glen flow law $d_{ij} = f.a \exp(-Q/RT^*) \tau^{n-1} \tau_{ij}$

where d_{ij} is a strain-rate component, τ_{ij} is the corresponding stress component, τ is the effective shear stress, T* is the absolute temperature corrected for the dependence of melting point on pressure, Q is the activation energy and R is the gas constant.

exponent n=3
enhancement factor f =3
coefficient a and activation energy Q
T* < 263.15 K a=1.14 10^{-5} Pa^{-3} yr^{-1} Q=60 kJ mol^{-1}
T* > 263.15 K a= 5.47 10^{10} Pa^{-3} yr^{-1} Q=139 kJ mol^{-1}

No sliding
Isostatic response *must be included*
Basal melting *must be taken into account both in the mass conservation equation and in the basal vertical velocity (add the basal melting as a vertical velocity)*

Thermal physical parameters

Geothermal flux :	50 mWm^{-2}
Triple point of water	273.15 K

ice

Thermal conductivity	2.1 W m^{-1} K^{-1}
Specific heat capacity	2009 J kg^{-1} K^{-1}
latent heat capacity	335 kJ kg^{-1}
Dependence of the pressure melting point on the depth	T* = 273.15 - 8.7 10^{-4} x depth (depth in meter)

bed

Thermal conductivity of the bed	3 W m^{-1} K^{-1}
Specific heat capacity for the bed	1000 J kg^{-1} K^{-1}

Ablation parameterisation *(degree day method, equation (5) in Huybrechts and al. 1991)*

Positive degree day factor for ice	8 mm d^{-1} $°C^{-1}$ (mm of water)
Positive degree day factor for snow	3 mm d^{-1} $°C^{-1}$

Superimposed ice : Runoff occurs when the superimposed ice layer exceed 60% of the yearly snowfall
The annual cycle of temperature is expressed as a cosine function
Standard deviation of the daily temperature 5°C

Precipitation rate: the experiment with level 2 is a steady state experiment with present climatic condition. We assume that precipitation rate is the same as given in the input file

(suaq).

INPUT FILES

The files are on the ftp anonymous of the LGGE in the directory:
pub/EISMINT-INTERCOMP/GREENLAND/INPUT-FILES

Topography

For each resolution the grids are given on the following format

1 file with the grid grid20-EISMINT or grid40-EISMINT

format

line 1 : nx ny resolution
line 2 : ' I J Latitude longitude'
line 3 ->end *for each node*

I (W-E or x direction)	column 1
J (S-N or y direction)	column 2
Latitude	column 3
Longitude	column 4

1 file with the topographical data : suaq20-EISMINT or suaq40-EISMINT

format:

line 1 : nx ny resolution
line 2 : ' S H B Accum'
line 3 -> end for each node

surface elevation	column 1
ice thickness	column 2
bedrock elevation	column 3
Precipitation rate	column 4

Climatic forcing

GRIP record : sum89-92-ss09-50yr.stp information in grip18O.readme
SPECMAP record specmap.017

The file for the sea-level forsing comes from the noaa server and can also been found there
ftp ftp.ngdc.noaa.gov or http:/www.ngdc.noaa.gov
The GRIP record has been provided by Sigfus Johnsen.

RESULTS

The result files must be put on the same ftp anonymous of the LGGE
directory pub/EISMINT-INTERCOMP/GREENLAND/RESULTS

Please send also an E-mail to catherine Ritz to warn that results have been sent.

Output format (in fortran)

* Surface and bedrock elevation, ice thickness and temperature should be in format (F9.3) time in format (I7) , position (I,J) in format (I3), and all the other variables in format (e12.5).
* At least one blanc between each column.
* If the model does not calculate a variable, please fill with the undefined value 999.999

There are several type of results: snapshots (horizontal fields and transect) and time dependent variables. Participants should also provide a file with information concerning their model (see info file)

Snapshots results

The snapshot results will give a picture of the ice sheet at given times
These times are the following.

Steady state simulation :
when the equilibrium is reached . snapshot name: T000

Climatic cycle simulation

time	snapshot name
-130 kyr	T130
-65 kyr	T065
-21 kyr	T021
-9 kyr	T009
present	T000

Greenhouse warming simulation

time		snapshot name
present	+ 50 years	T050
	+ 100	T100
	+ 500	T500

Horizontal 2d fields name **HF**

The format is the same as the gridded input data (surface, thickness, berock) except that there are more columns

format

line 1 : nx ny resolution
line 2 :
line 3 -> end for each node

Surface elevation (m)	column 1
ice thickness (m)	column 2
bed elevation (m)	column 3
basal temperature (°C difference with melting)	column 4
surface temperature (°C)	column 5
ablation rate (m/y ice equivalent)	column 6
accumulation rate (m/y ice equivalent)	column 7
velocity along x (m/y, vertically averaged)	column 8
velocity along y (m/y,vertically averaged)	column 9

Some people may want to give other fields (for example age of the ice at the bottom or depth of the transition glacial interglacial, thickness of the temperate basal layer .....). Then please contact Catherine Ritz so we can decide together which fields we add.

Vertical 2d fields on a E-W transect name **VF**

The transect is the closest to the GRIP location.

GRIP 72.58 N 37.64 W altitude 3238 m, thickness 3029 m
grid 20 km transect J=77
grid 40 km transect J=39

Format of the file

from I=1 to I=nx
from surface to bottom

x position (m, origin at I=0)	column 1
z position (m, origin at present sea level, upward)	column 2
Ux velocity (m/yr)	column 3
Uy velocity (m/yr)	column 4
Uz velocity (m/yr)	column 5
Temperature (°C,difference with the melting point)	column 6

Time dependent variables name **TV**

Every 100 years in the climatic cycle simulation (except for the "futur" period 0-500 years where it should be every 10 years)
Every 10 years in the Greenhouse warming simulation

Format of the file.

time (years, negative before present)	column 1
ice covered surface (m^2)	column 2
total ice volume (m^3)	column 3
mean accumulation rate over ice (m/y ice equivalent)	column 4
mean ablation rate over ice (m/y ice equivalent)	column 5
calving (m^3/y ice equivalent)	column 6
basal melting (m^3/y ice equivalent)	column 7
area with basal melting (m^2)	column 8
maximum surface elevation (m)	column 9
I position of the highest node	column 10
J position of the highest node	column 11

"over ice" and "ice covered" means the grid cells with a positive ice thickness and the grid cells that can receive ice flux from a neigbour. It is the case for example for the grid points on the boundary of the ice sheet (at least in the models where the boundary jumps from point to point).

Time dependent variables at GRIP name **GR**

This file is necessary only for the climatic cycle experiment.

time (years, negative before present)	column 1
surface elevation at GRIP (m)	column 2
ice thickness at GRIP (m)	column 3
basal temperature at GRIP real temperature (not corrected)	column 4
surface temperature at GRIP (°C)	column 5
accumulation rate at GRIP (m/y , ice equivalent)	column 6

closest point to GRIP
I=47 J=77 with the 20 km grid
I=24 J=39 with the 40 km grid

INFO file

The file can be either in ascii or in a postcript format
This file should include:
* reference where the model is described. If this paper is in press the authors should either give as many details as possibble in the info file or send a draft version.
* for the experiments with preferred set of parameters, all the parameters that are different from the prescribed ones.
* method for the numerical resolution of the mass conservation equation (type of spatial discretisation, staggered grids, ADI or other method ...)
* Thermomechanical coupling : which processes are included (advection, diffusion, strain heating, polythermal ice ...)
* Ablation parameterisation
* Accumulation rate parameterisation for different climatic conditions or/and ice sheet altitude
* Bedrock modelling: local or regional (lithosphere rigidity), diffusive or relaxed (asthenosphere).Is the drop of sea level taken into account ?
* Method for calving
* Other characteristic of the model ?

Names of the result files

"experiment name"//"type of result"//"time of snapshot (if necessary)"//.'name'

examples

SSL2HFT000.Doug
steady state,prescribed parameters,horizontal fields, snapshot at the end of the simulation, by Doug MacAyeal

CCL3VFT021.Catritz
Climatic cycle,free parameters,vertical field, time 21 k by Catherine Ritz

CCL3GR.Catritz
climatic cycle, free parameter, GRIP time dependent variable

GWL3TV.Tony
Greenhouse warming, free parameters, time dependent variables by Tony Payne

INFO.Philippe
Information on his model by Philippe Huybrechts.
If this file is postcript file then the name should be INFO-PS.name.
Participants can choose their extension name as long as there is no ambiguity with somebody else (please check with Catherine Ritz). The name can be in lower or upper case.

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