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Steady-state simulations of the Greenland ice sheet using a three-dimensional full-Stokes model

Hakime Seddik (1), Ralf Greve (1), Thomas Zwinger (2), and Olivier Gagliardini (3)

(1) Institute of Low Temperature Science, Hokkaido University, Kita-19, Nishi-8, Kita-ku, Sapporo 060-0819, Japan , (2) CSC – IT Center for Science Ltd., P.O. Box 405, FIN-02101 Espoo, Finland, (3) Laboratory of Glaciology and Environmental Geophysics, CNRS, UJF-Grenoble I, BP 96, F-38402 Saint-Martin d'Hères Cedex, France

A three-dimensional, thermo-mechanically coupled model is applied to the Greenland ice sheet. The model implements the full-Stokes equations for the ice dynamics, and the system is solved with the finite-element method (FEM) using the open source multi-physics package Elmer (http://www.csc.fi/elmer/).

The finite-element mesh for the computational domain has been created using the Greenland surface and bedrock DEM data with a spatial resolution of 5 km (Bamber and others, 2001). The study is particularly aimed at better understanding the ice dynamics near the major Greenland ice streams. For this purpose, mesh refinement to obtain improved computed solutions on these areas has been introduced. The meshing procedure starts with the bedrock footprint where a mesh with triangle elements and a resolution of 1 km are employed at the vicinities of the North-East Greenland Ice Stream (NEGIS) and the Jakobshavn (JIS), Kangerdlugssuaq (KL) and Helheim (HH) ice streams. A size function is then applied so that the mesh resolution becomes coarser away of the ice streams up to a maximum horizontal element size of 20 km. The final three-dimensional mesh is obtained by extruding the 2D footprint with 10 vertical layers, so that the resulting mesh contains 230760 prism elements and 132740 nodes.

The numerical solution of the Stokes and the heat transfer equations involves direct and iterative solvers depending on the simulation case, and both methods are coupled with stabilization procedures. The boundary conditions are such that the temperature at the surface is parameterized as a function of the latitude and the surface elevation, the geothermal heat flux at the bedrock is prescribed as spatially constant and the lateral sides are open boundaries.

The simulations have been conducted in order to obtain steady-state results for the velocity and temperature fields for the entire ice sheet. The model computes the results with both bedrock sliding and melting used alternatively so that their effects on velocities and temperature are assessed separately. The results are also compared with a shallow-ice approximation model. Furthermore, the project goal is to better assess the effects of dynamical changes of the Greenland ice sheet on sea level rise under global-warming conditions. For that purpose, the model will be run using the climate forcing experiments defined in the SeaRISE/ice2sea assessment projects.

Reference:
Bamber, J.L., R.L. Layberry, S.P. Gogenini. 2001. A new ice thickness and bed data set for the Greenland ice sheet 1: Measurement, data reduction, and errors. Journal of Geophysical Research 106 (D24): 33773-33780.

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