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Simulations of the Greenland ice sheet 200 years into the future with the full Stokes model Elmer/Ice

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The full Stokes thermo-mechanically coupled model Elmer/Ice is applied to the Greenland ice sheet. Elmer/Ice employs the finite element method to solve the full Stokes equations, the temperature evolution equation and the evolution equation of the free surface. The general framework of this modeling effort is a contribution to the Sea-level Response to Ice Sheet Evolution (SeaRISE) assessment project, a community-organized effort to estimate the likely range of ice sheet contributions to sea level rise over the next few hundred years (http://tinyurl.com/srise-lanl, http://tinyurl.com/srise-umt).

The present geometry (surface and basal topographies) is derived from data where the basal topography was created with the preservation of the troughs at the Jakobshavn Ice Stream, Helheim, Kangerdlussuaq and Petermann glaciers. A mesh of the computational domain is created using an initial footprint which contains elements of 5 km horizontal resolution and to limit the number elements on the footprint while maximizing the spatial resolution, an anisotropic mesh adaptation scheme is employed based on the Hessian matrix of the observed surface velocities. The adaptation is carried out with the tool YAMS and the final footprint is vertically extruded to form a 3D mesh of 320880 elements with 17 equidistant, terrain-following layers.

The numerical solution of the Stokes and the heat transfer equations employs direct solvers with stabilization procedures. The boundary conditions are such that the temperature at the surface uses the present-day mean annual air temperature given by a parameterization or directly from the available data, the geothermal heat flux at the bedrock is given by data and the lateral sides are open boundaries. A non-linear Weertman law is used for the basal sliding.

Results for the SeaRISE 2011 sensitivity experiments are presented so that seven different experiments have been conducted, grouped in three sets. The Set C (three experiments) applies a change to the surface precipitation and temperature, the set S (three experiments) applies an amplification factor to change the basal sliding velocity and the Set T (one experiment) combines the forcings. The experiments are compared to a constant climate control run beginning at present (epoch 2004-1-1 0:0:0) and running up to 200 years holding the climate constant to its present state.

Relative to the control run, the experiments with the changes to the surface precipitation and temperature (Set C) show a contribution to sea level rise of ˜5 cm SLE when a factor 1x is applied to the temperature and precipitation anomalies. A factor 1.5x produces a sea level rise of ˜10 cm SLE and a factor 2x produces a sea level rise of ˜20 cm SLE. The experiments with the amplification factor applied to the basal sliding velocity (Set S) show higher sensitivities. The scenario with an amplification factor of 3x produces a Greenland contribution to sea level rise of ˜70 cm SLE. An amplification factor of 2.5x produces a contribution of ˜46 cm SLE and an amplification factor 2x produces a contribution of ˜26 cm SLE. The combo run (factor 1x applied to the temperature and precipitation anomalies in combination with the doubling of the basal sliding) produces a contribution of 31 cm SLE.

Keywords: ice sheet, modeling, Greenland, SeaRISE