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Ice sheet sensitivity experiments as part of an assessment of long-term safety for a planned repository for spent nuclear fuel in Sweden

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An application to build a deep geological repository for spent nuclear fuel in Forsmark in south-central Sweden is currently under consideration by Swedish authorities. As part of the safety assessment, the response of the repository to an extensive glaciation over time scales of several hundred thousand years, in terms of ice thickness, bedrock depression and hydrostatic pressure, has to be evaluated. The most extensive glaciation over Eurasia recorded in geological proxies occurred during the MIS 6, at around 140 kyrs BP (Late Saalian glaciation). At this time, the few existing numerical ice-sheet reconstructions suggest that the Eurasian ice volume reached more than 70 m SLE, which is at least three times larger than during the Last Glacial Maximum (21 kyrs BP). The reconstruction of this ice sheet is complicated by the fact that the timing of the maximum ice volume may not have been coeval with the maximum eastern and southern extent of the Saalian ice sheet. In the present study, the maximum geographical extension of the Late Saalian glaciation serves as an extreme test case to assess the impact of ice thickness over the Forsmark repository site.

We use the 3D-thermodynamical ice sheet-ice shelves and ice stream model GRISLI (Ritz et al. 2001) to simulate the Northern Hemisphere ice sheet topography of the Late Saalian glaciation. The model is forced by steady-state climatic fields (surface air temperature and precipitation) computed using the coupled atmosphere-ocean Community Earth System Model (CESM, NCAR) at $\sim 1^\circ$x1° resolution, with boundary and forcing conditions representative for the MIS6 glacial maximum. Ice sheet simulations are run on a 20 km regular rectangular grid over the northern high latitudes and allow for floating ice.

First, as part of the model validation, we show a numerical reconstruction of the MIS 6 Eurasian ice sheet using standard parameters for lapse rate, PDD coefficients and basal hydrology. Second, sensitivity experiments are presented, studying the impact of model parameters such as surface mass balance parameters and schemes of calving and basal hydrology on the ice thickness. With this approach we are able to provide reasonable upper and lower bounds of ice thickness for a possible extreme glaciation over the Forsmark area.