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Evaluation of three methods of different levels of complexity to represent the interactions between the Greenland ice sheet and the atmosphere at the century time scale.

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Based on numerous studies showing implications of polar ice sheets on the climate system, the climate community recommended the development of methods to account for feedbacks between polar ice sheets and the other climate components. In this study we used three methods of different levels of complexity to represent the interactions between a Greenland ice sheet model (GRISLI) and a regional atmospheric model (MAR) under the RCP8.5 scenario. The simplest method, i.e. uncoupled, does not account for interactions between both models. In this method MAR computes varying atmospheric conditions using the same present-day observed Greenland ice sheet topography and extent. The outputs are then used to force GRISLI. The second method is a one-way coupling method in which the MAR outputs are corrected to account for topography changes before their transfer to GRISLI. The third method is a fully coupled method allowing the full representation of interactions between MAR and GRISLI. In this case, the ice sheet topography and its extent as seen by the atmospheric model is updated for each ice sheet model time step. The three methods are evaluated regarding the Greenland ice sheet response from 2000 to 2150. As expected, the uncoupled method shows a coastal thinning of the ice sheet due to a decreasing surface mass balance for coastal regions related to increased mean surface temperature. The one-way coupling and the full coupling methods tend to amplify the surface mass balance due to surface elevation feedback. The uncoupled method tends to underestimate the Greenland ice sheet volume reduction compared to both coupling methods over 150 years. This underestimation is of the same order of magnitude of the ice loss from the Greenland peripheral glaciers at the end of the 21st century. As for the uncoupled method, the thinning of the ice sheet occurs in coastal regions for both coupling methods. However compared to the one-way coupling method, the fully coupled method tends to increase the spatial variability of the surface mass balance changes through time. Our results also indicate that differences between the two coupling methods increase with time, which suggests that the choice of the method should depend on the timescale considered. Beyond century scale projections the fully coupled method is necessary in order to avoid underestimation of the ice sheet volume reduction, whilst the one-way method seems to be sufficient to represent the interactions between the atmosphere and the GrIS for projections by the end of the century.