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An improved numerical scheme to compute horizontal gradients at the ice-sheet margin: its effect on the simulated ice thickness and temperature

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In three-dimensional numerical ice-sheet models that use finite difference schemes, the position of ice margins is poorly represented with a regular quadratic grid. As a result, in a centered difference scheme, the surface gradient term and the flux divergence term computed for the grid points next to the ice margin may be inaccurate. In this study, an improved scheme is presented that computes the horizontal gradients at the ice-sheet margin using an asymmetric (upstream) second-order and higher difference scheme in order to avoid using information from the zero-thickness grid points. The model is applied to an idealized synthetic geometry to obtain a steady-state ice sheet topography. The improved model shows a realistically smooth thickness distribution near the margin. Thermo-mechanical coupling is found to enhance the error near the margin. The error in simulated thicknesses with the centered-difference method was significantly reduced with the new upstream scheme. Influence on the error from different orders used in the finite difference schemes, as well as resolutions or numerical schemes, are discussed. The model with new scheme is also applied to Greenland ice sheet, and influence on global warming simulation is discussed.