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A comparison of the shallow ice approximation with the full Stokes equation in glacier dynamics simulations

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The Shallow Ice Approximation (SIA) is a widely used approach to model ice-sheet and even glacier flows. This is mainly motivated by simplifications introduced by expanding the governing equations into power series of the aspect ratio ζ of the modelled ice body. The fact that the SIA represents the limit $\zeta \rightarrow 0$ raises questions as to its applicability to ice bodies that either globally or locally violate the assumption of a vanishing aspect ratio, as it is the case for alpine glaciers.

Comparison of results obtained with a SIA Finite Difference model with those of a Finite Element Method (FEM) in which the flow equations are fully considered for a set of two and three-dimensional flow tests indicates a decrease of the accuracy of the SIA linked to increasing bedrock slopes rather than to increasing aspect ratio ζ (resulting from higher accumulation rates). Thus, we conclude that in the case of pronounced slopes a bedrock-related aspect ratio should provide a better criterion for assessing the validity of the SIA approach. This is substantiated by the indication of a misfit of longitudinal shear stress components between three-dimensional SIA and full Stokes system simulation results.