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3D numerical modeling of the lateral transition between viscous overthrusting and folding with application to the Helvetic nappe system

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The Helvetic nappe system of the European Alps is generally described as a complex of fold and thrust belts. While the overall geology of the system has been studied in detail, the understanding of the tectonic development and mechanical interconnection between overthrusting and folding is still incomplete. One clue comes from the mechanical stratigraphy and the corresponding lateral transition from overthrusting to folding, which is characteristic for the Helvetic nappe system. We employ a three-dimensional numerical model with linear and non-linear viscous rheology to investigate the control of the lateral variation in the thickness of a weak detachment horizon on the transition from folding to overthrusting during continental shortening. The model configuration is based on published work based on 2D numerical simulations. The simulations are conducted with the three-dimensional staggered-grid finite difference code LaMEM (Lithosphere and Mantle Evolution Model), which allows for coupled nonlinear thermo-mechanical modeling of lithospheric deformation with visco-elasto-plastic rheology and computation on massive parallel machines. Our model configuration consists of a stiff viscous layer, with a pre-existing weak zone, resting within a weaker viscous matrix. The reference viscosity ratio μL/μM (for the same strain rate) between the layer and matrix ranges from 10 to 200. The simulations were run with several distinct initial geometries by altering the thickness of the detachment horizon below the stiff layer across the configurations. Shortening with a constant bulk rate is induced by the prescription of a horizontal velocity on one side of the model. The first results of our simulations highlight the general importance of the initial geometry on the lateral transition from overthrusting to folding. Additionally, models with a stepwise lateral variation of the detachment horizon indicate a fold development orthogonal to the main compressional axis.