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Numerical modelling of lithospheric deformations with frictional plasticity

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Strain localisation is a key process that allows for the emergence of tectonic plates and controls their long-term deformation. Upper crustal levels are relatively cold and their rheology is thus governed by frictional plasticity. In order to predict the formation of tectonic plates and quantify the deformation of the Earth's upper shell, geodynamic modelling simulation tools must reliably account for deformation in the frictional plastic realm.

Nevertheless, the simulation of frictional plastic strain localisation poses severe issues. Commonly employed implementations (visco-plastic and visco-elasto-plastic) often fail to accurately satisfy force balance and suffer from a lack of convergence upon mesh refinement. These problems are intimately linked to the fact that commonly employed models do not encompass any characteristic spatial or temporal scales of localisation. Various regularisation techniques can thus be used as a remedy. Here we investigate three popular regularisation techniques, namely viscoplasticity, gradient plasticity and the use of a Cosserat medium, and discuss their potential application for geodynamic modelling.