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Towards three-dimensional continuum models of self-consistent along-strike megathrust segmentation

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At subduction megathrusts, propagation of large ruptures may be confined between the up-dip and down-dip limits of the seismogenic zone. This opens a primary role for lateral rupture dimensions to control the magnitude and severity of megathrust earthquakes. The goal of this study is to improve our understanding of the ways in which the inherent variability of the subduction interface may influence the degree of interseismic locking, and the propensity of a rupture to propagate over regions of variable slip potential.

The global absence of a historic record sufficiently long to base risk assessment on, makes us rely on numerical modelling as a way to extend our understanding of the spatio-temporal occurrence of earthquakes. However, the complex interaction of the subduction stress environment, the variability of the subduction interface, and the structure and deformation of the crustal wedge has made it very difficult to construct comprehensive numerical models of megathrust segmentation. We develop and exploit the power of a plastic 3D continuum representation of the subduction megathrust, as well as off-megathrust faulting to model the long-term tectonic build-up of stresses, and their sudden seismic release.

The sheer size of the 3D problem, and the time scales covering those of tectonics as well as seismology, force us to explore efficient and accurate physical and numerical techniques. We thus focused our efforts on developing a staggered grid finite difference code that makes use of the PETSc library for massively parallel computing. The code incorporates a newly developed automatic discretization algorithm, which enables it to handle a wide variety of equations with relative ease.

The different physical and numerical ingredients — like attenuating visco-elasto-plastic materials, frictional weakening and inertially driven seismic release, and adaptive time marching schemes — most of which have been implemented and benchmarked individually — are now combined into one algorithm. We are working towards presenting the first benchmarked 3D dynamic rupture models as an important step towards seismic cycle modelling of megathrust segmentation in a three-dimensional subduction setting with slow tectonic loading, self consistent fault development, and spontaneous seismicity.