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Slab width as the dominant factor in determining trench migration velocity and subduction zone curvature

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Subducting slabs provide the main driving force for plate tectonics and flow in the Earth's mantle. Geodynamic modelling provides insight into the sinking kinematics and dynamics of slabs, and subduction-induced flow. Many previous numerical studies modelled subduction either in 3D space with essentially static models, or modelled subduction in 2D space. Laboratory simulations of subduction are evidently conducted in 3D space, but many early models only focussed on 2D aspects of the modelling. In nature, subduction zones and their associated slabs are three-dimensional features with curved geometries and a limited trench-parallel extent (i.e. limited slab width). In addition, the trench velocity varies significantly along individual trenches (up to 20 cm/yr). Only recently have laboratory and numerical models started to focus on subduction processes in three-dimensional space. Here we present results from numerical simulations of free subduction in a stratified mantle reservoir, showing the progressive evolution of subduction in three-dimensional space. The models are specifically designed to investigate the influence of slab width on the subduction process. The sub-lithospheric upper and lower mantle reservoirs are modelled with linear viscosities, while the plate is modelled with a viscoplastic upper half and a viscous lower half. The results show that the trench migration velocity can vary about an order of magnitude due to variation of slab width. The evolution of the trench geometry is also found to depend on the width of the slab with observed geometries ranging between concave, sub-linear and convex. The numerical results are compared to a new global compilation of trench velocity calculations and to subduction zone geometries on Earth, and are found to explain the first-order global trench migration patterns and subduction

zone geometries. The numerical models can also explain the long-term evolution of the subduction zone geometry as illustrated with reconstructions of several subduction zones on Earth. It is found that the simple rheologies and geometries adopted in the numerical simulations can explain a wide variety of subduction zone characteristics as observed on Earth.