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Self-consistent orogenic wedge formation and shear zone propagation due to thermal softening

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We present two dimensional numerical simulations of orogenic wedge formation for a viscoelastoplastic lithosphere under compression. The thermo-mechanical model is based on the principle of energy conservation and includes temperature-dependent rheologies. With this approach, shear zones caused by thermal softening develop spontaneously in the absence of strain softening. The initial locus of shear localization is controlled by either lateral temperature variations (100°C) at the model base or by lateral variations in crustal thickness. The first episode of strain localization occurs after 15% bulk shortening. With ongoing strain, a series of shear zones arise and propagate towards the foreland leading to the self-consistent formation of an orogenic wedge. We investigate the impact of bulk shortening rates, erosion and rheology on the dynamics of wedge formation, the associated topography and uplift rates. The maximum topography reaches up to 10 km and the surface morphology evolves according to shear zone activation and deactivation. Uplift rates are transient and peak values are maintained only on very short time scales. A running average of the uplift rate versus time curves with a time-window of 4 My provides average uplift rates in the order of a few millimeters per year. Erosion is an important parameter for the formation and the evolution of the wedge (e.g. can control the spacing of shear zones by modifying crustal thickness). Rheological parameters, such as the friction angle or the upper crustal viscosity, control the occurrence of strain localization. Bulk shortening rates between 10^{-15} and 10^{-16} s^{-1} do not have a major impact on the resulting wedge structure.