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The influence of surface processes in modulating the deformation of the deep lithosphere during collision

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The importance of climate-controlled surface processes (erosion and deposition) in influencing the tectonics of plate collision and orogenesis has been well recognized for crustal-scale tectonics. We consider the geodynamics of coupled crust and mantle processes during such collisional events to consider how the surface processes modify the deformation of the deeper parts of the plate and lithosphere as a whole. The geodynamics are explored quantitatively using high resolution 2D thermal-mechanical numerical experiments. The model has a free surface, prescribed erosional laws (e.g., empirically derived relief- and slope-dependent erosion), and sediment deposition dependent on the amount of material eroded make up the top boundary of the model domain and allow topography to develop self consistently with the underlying tectonics. The models reveal that during the early stages of continental plate collision, the altered of crustal mass flux by surface erosion can modify the stress regime within the crust and at the crust-mantle interface and subsequently the behaviour of the underlying mantle lithosphere. For example with active surface erosion stable subduction-like plate consumption is maintained. In the absence of erosion, subduction is inhibited by accumulating crust causing the convergent plates to steepen dip, detach, and reverse consumption polarity. We also isolate the influence of sediment deposition in the collisional models. In very different ways, the surface transport and deposition of the eroded material can have a significant effect on modulating the dynamics of the whole lithosphere between various modes of deformation. Overall, the models reveal the sensitivity of the near-surface and deep continental plate boundary evolution to surface processes.