



Episodic Plate Motion and Thermal Structure in Subduction Zones Caused by Slab Folding in the Transition Zone

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Plate reconstruction models show that individual plates experience episodes of fast versus slow subduction rates, and likely experience episodes of advancing, stationary or retreating trench motion (Sdrolias and Müller, 2006), although 62-78% of present-day slabs are likely in trench retreat (Schellart et al., 2008). However, most laboratory and numerical simulations predict steady plate velocities and sustained uni-directional trench motion accounting for a large proportion of the net convergence (Stegman et al., 2010; Funicello et al., 2003; Garel et al., 2014; Cížková and Bina, 2013; Agrusta et al., 2017). We used 2D dynamical models of subduction with a mobile trench and overriding plate, non-linear composite rheology, and compositionally-dependent phase transitions to further explore how slab deformation couples to plate and trench motion and the thermal structure of the slab and mantle wedge. We find that the combined effect of phase transitions and increasing viscosity causes episodic slab folding in the transition zone. The frequency and magnitude of folding depend on the plate age, and relative slab/mantle viscosity, as has been found in previous studies (Ribe, 2010; Lee and King, 2011). Slab folding is accompanied by pulses of fast subduction and trench retreat. The proportion of trench retreat (19%) is increased by adding crustal density to the overriding plate (49%), adding a spreading ridge to the edge of the overriding plate (60%), and increasing the minimum asthenosphere viscosity (86%). However, in none of the models is there rapid, steady trench retreat. Fast sinking of the slab during folding events causes a reduction in asthenosphere viscosity through the non-linear rheology, which allows the overriding plate to completely decouple from the underlying asthenosphere (i.e., the plate moves in the opposite direction of the asthenosphere). This decoupling causes a return to trench advance after each slab folding event. These results show that non-linear viscosity plays an important role in determining the force balance controlling trench motion and trench motion can be used as a direct constraint on the asthenosphere viscosity outside the mantle wedge. Fast subduction during folding also leads to episodes of cold (-200 C) slab surface temperatures relative to the steady-state behavior of slabs when no phase transitions are present. Such cold episodes would also likely lead to time-variability in the water content and related geochemical tracers in erupted lavas, as well as the amount of water being transported by slabs into the deep mantle. Mantle wedge temperatures do not exhibit a strong dependence on subduction rate, but instead show that increasing the minimum mantle viscosity can lead to cooling of the mantle wedge through progressive shallowing of the slab dip.