Time-varying subduction and rollback velocities in slab stagnation and buckling

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Models of subducting slabs exhibit buckling behavior in or below the mantle transition zone for certain combinations of dynamical parameters [Christensen, 2001]. Slabs that descend below the transition zone exhibit buckling instabilities in the lower mantle in response to viscosity increases [Ribe et al., 2007]. Numerical experiments for such vertically descending slabs exhibit buckling for large (>30x) viscosity increases and slow (imposed) trench migration, manifesting as temporal oscillations in dip angle and convergence rate [Lee and King, 2011]. Here we focus upon buckling behavior in subducting slabs that "stagnate" [Fukao et al., 2009] via subhorizontal deflection in the transition zone (due to some combination of buoyancy variations, viscosity contrasts, and slab rollback). We perform numerical experiments using a 2D Cartesian model of the mantle. Subducting and overriding plates are 5000 km long, separated by a 15-km thick weak crustal layer [Chertova et al., 2012]. The age of the subducting plate at the trench is 100 Ma or 150 Ma; yield stress that controls slab strength in the upper mantle varies between 0.2 GPa and 1 GPa. Analysis of the evolution of subduction velocities (after the tip of the slab descends below 400 km) reveals temporal oscillations of order 10 cm/yr with periods of order ~20 Myr (similar to the ~25 Myr periods obtained [Lee and King, 2011] for vertically descending slabs) in response to repeated slab buckling within the transition zone. Periods of these oscillations increase with increasing slab strength controlled by the yield stress, while the amplitude of the plate velocity peaks is higher for weaker slabs. Our models also yield corresponding oscillations in slab rollback velocities, which are an order of magnitude smaller and phase shifted (by ~180°). Rollback velocities are higher for older and thus more negatively buyoant slabs. Our results may shed more light on the conditions needed to produce flat lying slabs as observed in some parts of the mantle transition zone.

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