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Short-lived, long-lived and periodic flat slab subduction

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Flat slab subduction occurs when the subducted slab lies flat below the base of the overriding plate for up to several hundred kilometres before bending into the deeper mantle. It has been ascribed to a variety of causes, including subduction of buoyant ridges/plateaus and forced trench retreat. Ridge/plateau subduction, however, shows irregular spatial correlations with flat slabs, while forced trench retreat has required external forcing in geodynamic subduction models, which might be insufficient or absent in nature. Here we present buoyancy-driven numerical geodynamic models and aim to investigate flat slab subduction in the absence of external forcing. Furthermore, we test the influence of a variety of subduction zone parameters, including overriding plate strength and subducting plate thickness, on flat slab formation and its evolution. Flat slab subduction is reproduced during normal oceanic subduction in the absence of ridge/plateau subduction and without externally forced plate motion. Flat slab subduction only commences after a prolonged period of upper mantle slab dip angle reduction during lower mantle slab penetration. The flat slab is supported by mantle wedge suction, vertical compressive stresses at the base of the slab and upper mantle slab buckling stresses. Our models demonstrate three modes of flat slab subduction, namely short-lived (transient) flat slab subduction, long-lived flat slab subduction, and periodic flat slab subduction, which occur for different model parameter combinations. Most models demonstrate slab folding at the 660 km discontinuity, which produces periodic changes in the upper mantle slab dip angle. With relatively high overriding plate strength, such folding results in periodic changes in the dip angle of the flat slab segment, which can lead to periodic flat slab subduction, providing a potential explanation for periodic arc migration. Flat slab subduction ends due to the local overriding plate shortening and thickening it produces, which forces mantle wedge opening and a reduction in mantle wedge suction. As overriding plate strength controls the shortening rate, it has a strong control on the duration of flat slab subduction, which lasts only ~6 Myr for the weakest plate and exceeds 75 Myr for the strongest plate. Progressive overriding plate shortening during flat slab subduction might explain why flat slab subduction terminated in the Eocene in western North America and in the Jurassic in South China.