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Water migration in the subduction mantle wedge: a two-phase flow approach

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Subduction zones are the main entry points of water into earth's mantle and play an important role in the global water cycle. The progressive release of water by metamorphic dehydration induces important physical-chemical process and may play an important role in the generation of subduction zone earthquakes. Yet, how water migrates in subduction zones is not well understood. We investigate this problem by explicitly modeling a two-phase flow during subduction, in which the fluid migrates through compaction and decompaction of the solid matrix. Our results show that fluid migration may occur preferentially along the subduction interface from where it feeds into the mantle wedge. This process is strongly affected by the dynamics of the subduction process in our model, which includes in three characteristic phases: (1) an early stage of subduction initiation; (2) an intermediate stage of gravity-driven steepening of the slab; and (3) a late stage where the slab becomes supported from the bottom. With a background porosity of φ_0= 2x10^{-4}, water is able to migrate horizontally up to $\sim$300 km from the subduction trench: the deeper the water releases from the subducting slab, the further it can migrate horizontally. The models suggest the mantle wedge may be characterized by a lower permeability zone surrounding by two high porosity pathways, which is consistent with Vp/Vs ratio anomalies observed in tomographic models of some subduction zones (e.g., western Greece). We further find that (de)compaction enhances fluid migration significantly and water can still migrate into the mantle wedge even under very low background porosity and permeability (e.g. φ_0= 2x10^{-5} and k_0=10^{-25}). The feedback of fluid migration on the solid dynamics, which is not included here, will be subject of further study and is anticipated to play an important role in the subduction dynamics.