The pattern of fluid release from the subducting slab and the migration of fluids in the mantle wedge

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In this study, we use numerical models to quantify the pattern of fluid release from the subducting slab and the migration path of aqueous fluids in the mantle wedge in subduction zones. The release and uptake of H_2O by dehydration and hydration reactions, respectively, are calculated using a subduction zone thermal model and thermodynamic calculations based on Perple_X. To date, most studies of fluid flux in subduction zones have assumed a uniform distribution of mineralogically bound H_2O within given lithologies in the incoming plate. However, geological and geophysical observations and thermo-mechanical models indicate that the distribution of hydrous phases in the lower crust and upper mantle can be highly localized due to fault-controlled fluid migration and hydration. Our modeling results show that for a given bulk H_2O content, localized hydration results in shallower H_2O release compared to uniform hydration, and that the H_2O flux off the subducting slab beneath the forearc and arc regions can be almost twice as large from a locally hydrated slab as from a uniformly hydrated slab. Hydration of the overlying mantle in the flowing part of the wedge leads to downdip transport of bound water by the flowing mantle and delays the liberation of H_2O, but the volume of H_2O absorbed in the mantle is small compared to that released from the subducting slab. We model the migration of the released aqueous fluids in the hot flowing part of the mantle wedge excluding the cold stagnant wedge corner. Mineral grain size affects grain-scale permeability of the mantle and fluid migration. Our thermal model coupled with a laboratory-derived grain size evolution model predicts a large spatial variation in grain size in the flowing part of the wedge; grain size increases from 10–100 microns in the shallowest part of the region beneath the forearc to a few cm in the hottest part of the mantle beneath the arc. By incorporating the grain size distribution into a fluid migration model, we find that aqueous fluids that migrate into the shallow fine-grain-size region become trapped in the downgoing mantle due to low permeability and are dragged downdip until permeability becomes high enough for the fluids to migrate upward. Thus, the grain size distribution can play an important role in controlling the location of upward fluid migration. A number of processes in subduction zones, such as arc magma generation, earthquakes, and mantle flow, depend strongly on the availability of aqueous fluids at depth. Using our modeling results, we explore the implications of the predicted fluid distribution on various subduction zone processes.