Mass balance of the arc with a mantle-wedge melting model

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The mass balance problem in subduction zones is important because (a) subduction flux is returned to the mantle; (b) increasing P-T conditions eject melt and fluid from the subducting slab; (c) the return fluxes migrate back into the mantle wedge as dehydrated fluids or silicate melts causing melting or interaction with mantle peridotite to generate magma; and then (d) the magma returns to the surface forming the arc crust by solidification, and supplies volatiles to the air and ocean systems by degassing. All of these conditions are closely related to major geological processes and thus the earth's history. However, mass balance calculations in this complex region contain numerous uncertainties. These include (a) amount of subducted mass in a given time interval; (b) the proportions of material subducted, such as altered oceanic crust (AOC) or sediments (SED); (c) complex geochemical reactions between different source materials with differing mineralogy and at different P-T conditions; and (d) the amount of material added to the crust, among others. Researchers have made many attempts to assess mass balances by examining magma production rate, crustal growth rate, volatile mass balance, and other factors. For simplicity, the mass balance at the mantle wedge is regarded as the difference between the input mass at the trench and the output mass observed by crustal growth or by degassing rate. The residue of the equation is the mass returned back into the deep mantle. Mass balance calculations of this sort can neglect complexities in chemical reactions occurring at the slab and mantle wedge. The chemical reactions in these regions have been investigated intensively by experimental petrology, and considerable knowledge of these processes has now accumulated. Building on the progress made in the chemistry at mantle depths, the melting problem in a normal arc mantle can be simplified using a one-box model. The materials required are a depleted mantle (DMM) melted by fluid fluxes derived from AOC or SED. P-T-fluid-flux-rate melting conditions are estimated by inverse modeling from the basalt magmas generated. The mass balance of a single box is deduced from the total fluid influx rate, the DMM influx rate, and the basalt magma outflux rate. Given the crustal growth rate by magma underplating, the above equation is solved semi-quantitatively. The remaining uncertainties are the average degree of melting and the volume of the molten region at the mantle wedge. These factors can be constrained by seismic tomography images. We here propose a one-box mantle melting mass balance model to further constrain the mass balance of the island arc.