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Beyond uplift-weathering: metamorphic decarbonation dominates the carbon budget of the central Apennines

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Recent views on mountain building and chemical weathering have recognized that the balance of CO_2 sources and sinks is primarily controlled by weathering of sedimentary organic carbon, carbonate, and sulfide in the critical zone. However, the focus on near-surface weathering reactions does not consider metamorphic CO_2 emissions from subduction processes, which are suggested to outpace CO_2 drawdown in mountain ranges that subduct large volumes of carbonate rock. Thus, accounting for weathering processes at depth and in the critical zone in parallel is crucial to fully assess how mountain-range uplift impacts the carbon cycle. Here, we employ geochemical and geophysical observations to quantify the carbon balance from subduction-related processes and from critical zone weathering reactions in two major river systems in the central Apennine Mountains of Italy. The studied catchments straddle a geodynamic gradient across the subduction zone, with relatively constant climatic conditions. At the regional scale, we find that metamorphic CO_2 sources outpace critical zone inorganic carbon sources and sinks by 2 orders of magnitude above a window in the subducting slab that is characterized by high heat flow and low crustal thickness, and could have driven efficient degassing over the last 2 Ma. In contrast, surficial weathering processes dominate the carbon budget where crustal thickness is greater and heat flow is lower. In subduction-extensional settings such as the Apennines, modulations of metamorphic decarbonation reactions may be a more efficient process by which tectonics can regulate the inorganic carbon cycle than modulations of surficial weathering reactions. Thus, a geodynamic framework must be considered in conjunction with critical zone processes to understand the true impact of mountain building on the carbon cycle and to understand long-term evolution of atmospheric CO_2.