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Catchment-scale modeling of soil carbon dynamics using the Radiocarbon Inventories of Switzerland

Alexander Brunmayr[1,2,3], Margaux Moreno-Duborgel[2,4], Luisa Minich[2,4], Timo Rhyner[2,5], Benedict Mittelbach[2,6], Margot White[2,7], Negar Haghipour[2,8], Frank Hagedorn[4], Timothy Eglinton[2], and Heather Graven[3]

[1]Department of Environmental Systems Science, ETH Zurich
[2]Department of Earth and Planetary Sciences, ETH Zurich
[3]Department of Physics, Imperial College London
[4]Forest Soils and Biogeochemistry, Swiss Federal Institute WSL
[5]Schweizerische Greina-Stiftung
[6]Division of Geological and Planetary Sciences, California Institute of Technology
[7]Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia
[8]Laboratory for Ion Beam Physics, ETH Zurich

With air temperature anomalies already reaching +3°C, Switzerland is undergoing rapid environmental change, particularly in the Swiss Alps, experiencing alpine greening and an upward shift of the tree line. However, the consequences of these changes for soil carbon storage, turnover, and lateral export remain poorly constrained. Using the national Radiocarbon Inventories of Switzerland database (RICH, rich.ethz.ch), we combine highly informative 13C and 14C isotopic data with a coupled soil–rock–water model to investigate carbon cycle dynamics across spatial scales, from individual sites to entire catchments. At the local scale, isotopic measurements of soil density fractions provide detailed insights into carbon stabilization mechanisms and turnover times. Meanwhile at the catchment scale, riverine ion concentrations and carbon isotopic signatures integrate signals across landscapes. Long-term continuous monitoring of river carbon and solute fluxes over the past 50 years reveal significant changes across both the Swiss Plateau and Alps, reflecting shifts in weathering, hydrology, and soil carbon cycling. By jointly calibrating site-scale soil processes and catchment-scale riverine fluxes using isotopic constraints, our approach enables cross-scale inference of carbon turnover and pathways. With this integrated framework, we aim to improve our understanding of the coupling between vegetation dynamics, soil carbon turnover, bedrock weathering, and lateral carbon export in vulnerable landscapes undergoing change.