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A general framework for modelling the vertical organic matter profile in mineral and organic soils

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The vertical distribution of soil organic matter (SOM) within the mineral soil and surface organic layer is an important property of terrestrial ecosystems that affects carbon and nutrient cycling and soil heat and moisture transport. The overwhelming majority of models of SOM dynamics are zero-dimensional, i.e. they do not resolve heterogeneity of SOM concentration along the vertical profile. In recent years, however, a number of new vertically explicit SOM models or vertically explicit versions of existing models have been published. These models describe SOM in units of concentration (mass per unit volume) by means of a reactive-transport model that includes diffusion and/or advection terms for SOM transport, and vertically resolves SOM inputs and factors that influence decomposition. An important assumption behind these models is that the volume of soil elements is constant over time, i.e. not affected by SOM dynamics. This assumption only holds if the SOM content is negligible compared to the mineral content. When this is not the case, SOM input or loss in a soil element may cause a change in volume of the element rather than a change in SOM concentration. Furthermore, these volume changes can cause vertical shifts of material relative to the surface. This generally causes material in an organic layer to gradually move downward, even in absence of mixing processes. Since the classical reactive-transport model of the SOM profile can only be applied to the mineral soil, the surface organic layer is usually either treated separately or not explicitly considered.
We present a new and elegant framework that treats the surface organic layer and mineral soil as one continuous whole. It explicitly accounts for volume changes due to SOM dynamics and changes in bulk density. The vertical shifts resulting from these volume changes are included in an Eulerian representation as an additional advective transport flux. Our approach offers a more elegant and realistic description of the SOM profile that does not rely on an arbitrary separation between the organic layer and the mineral soil. Furthermore, it is applicable to any type of soil, included peatland soils and soils influenced by erosion.