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Representing soil microbial processes explicitly in global land surface model

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Our understanding of soil organic carbon (SOC) decomposition and stabilization have undergone significant revisions during the past two decades. However, global land surface models (LSMs) used to study carbon cycle-climate feedbacks continue to mostly use simplistic first-order kinetics SOC modules. Therefore, soil microbes and the latest understanding of SOC decomposition and stabilization have not been explicitly represented in these LSMs. In this study, we integrated the latest understanding of SOC stabilization and microbial decomposition processes into the LSM ORCHIDEE-CNP, which simulates the water, energy, carbon, nitrogen and phosphorus fluxes in terrestrial ecosystems. In the new ORCHIDEE-CNPmic, two microbial functional types are represented that roughly correspond to microorganisms with copiotrophic and oligotrophic growth strategies following the MIMICS model, and SOC is divided into three functional pools: the physically protected, the chemically recalcitrant, and the available pool. Decomposition of litter and SOC is simulated based on temperature-sensitive Michaelis–Menten kinetics. Microbial carbon use efficiency is calculated from the stoichiometry of substrates and the availability of soil nutrients. Different from its presursor MIMICS, our soil model also represents microbial dormancy, the constraint of soil moisture on microbial decomposition rate, and the maximum SOC adsorption capacity of the soil minerals.

ORCHIDEE-CNPmic simulates gross and net primary production of global vegetation as well as the default ORCHIDEE-CNP. The simulated global total SOC stock and its distribution along latitudinal gradient are comparable to those provided by observation-based global soil databases. The simulated fractions of the physically-protected SOC pool to the total SOC are similar to the fractions of mineral-associated organic carbon measured at globally-distributed forest and grassland sites. In addition, simulated ratios of microbial biomass to total SOC stock for different types of forest, grassland and cropland sites are overall comparable to field observations. Lastly, ORCHIDEE-CNPmic capture well the SOC decomposition rates measured at seven sites in Europe during the long-term bare fallow experiments. Overall, this study developed and rigorously tested a new LSM with explicit representation of soil microbial decomposition processes. ORCHIDEE-CNPmic will be a useful tool to explore the interactions between microbial activity and SOC dynamics under changing climate at global scales.