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Spatially heterogeneous mechanisms underlying soil carbon sequestration as revealed via big data-driven Earth system modelling and deep learning

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It has long been known that processes that determine soil carbon dynamics are spatially heterogeneous. However, the spatially heterogeneous mechanisms have not been well characterized nor incorporated into Earth system models for predicting soil carbon sequestration in response to climate change. This presentation shows our recent results from an integrated approach that combines deep learning, data assimilation, big data with >100,000 vertical soil organic carbon (SOC) profiles worldwide, and the Community Land Model version 5 (CLM5) to optimize the model representation of SOC over the world. Our results indicate that CLM5 that is trained by >100,000 data via data assimilation alone is constrained with spatially homogeneous parameter values over the globe. However, CLM5 that is not only trained by data assimilation but also optimized by deep learning from the big data is constrained with spatially heterogeneous parameter values. Our further analysis suggests that those parameters representing microbial carbon use efficiency greatly vary across space. The spatial heterogeneity in carbon use efficiency is caused by interactions of edaphic, climate and vegetation factors. When the spatially heterogenous parameterization is applied to simulation over time with temporal variation, CLM5 predicts substantial carbon sequestration under climate change. In contrast, CLM5 with the spatially homogeneous parameters predicts carbon loss. Our study demonstrates the importance to uncover and represent spatially heterogeneous mechanisms underlying soil carbon sequestration in order to realistically predict SOC dynamics in the future.