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Spatial patterns of carbon turnover times and their environmental drivers

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The carbon turnover time, defined as the ratio of mass and flux from a carbon pool under steady state assumption, is one of the key parameters determining terrestrial carbon balance. It has also been suggested that uncertain carbon turnover time as an emerging property of models dominates the uncertainty in terrestrial vegetation and soil responses to future climate change and rising atmospheric CO_2 concentration. Therefore, researches on the carbon turnover times and their relations with environmental factors should be a priority for current terrestrial carbon cycle studies.

Based on previous progress (Wu et al. 2018), we further studied the ecosystem carbon turnover times, dividing to vegetation and soil system as well, using multisource carbon storage and flux data and eighteen state-of-the-art ecosystem models (Trendy DGVM). The results showed that about 70% models underestimated global τveg (data-ensemble of 10±2 yr vs model-ensemble of 8±2 yr), τsoil (data-ensemble of 28±2 yr vs model-ensemble of 24±10 yr), and τeco (data-ensemble of 38±3 yr vs model-ensemble of 31±11 yr). The underestimation of global carbon turnover times in ecosystem models was mainly due to values for τveg and τsoil being too low in the high northern latitudes and arid and semiarid regions. In addition, the models did not capture the data-based spatial climate sensitivity of carbon turnover time in these regions. Modeled τveg and τsoil were generally weakly, or even opposite sign, correlated with climate variables.

Mismatched model-data based apparent climatic sensitivities implied that we currently lack enough knowledge of the underlying processes driving global or regional carbon turnover times. Using a powerful machine-learning approach based on traditional regression tree methods, we established robust relationships between observed environmental factors (temperature-related, precipitation-related, soil-related and forest cover) and carbon turnover times. The results showed that global τveg was primarily dominated by forest cover (relative contribution of 24%), mean annual temperature (16%) and temperature seasonality (11%); and the global τsoil was mainly influenced by icedays (28%), nitrogen (21%) and mean annual temperature (18%). By contrast, nearly all model-based τveg was strongly dominated by forest cover (62±18%); and half of model-based τsoil were mainly influenced by temperature-related factors, and the other half were mainly explained by precipitation-related factors. These results indicated that current models poorly considered the climate-τveg processes, and there are still half models unable to capture the temperature-dominated τsoil patterns. These results highlighted the emergency need for improving the model parameterization of carbon turnover related processes and adding key processes such as carbon-nitrogen interactions and permafrost-carbon climate responses.

References:

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