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What drives global biomass turnover? A view from global vegetation models

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Understanding the current and future contribution of the terrestrial biosphere to the global carbon budget remains a priority for terrestrial ecosystem science. Recent years have seen a gradual shift in focus to better understanding not only primary productivity, but also rates of carbon turnover in terrestrial ecosystems. Large-scale productivity and biomass datasets have provided first estimates of how rates of biomass turnover vary globally, but information on the drivers of turnover, and the extent to which turnover times might now be out of equilibrium with productivity due to changing environmental conditions, remains scant. In order to balance their carbon budgets within known constraints at a variety of scales, global vegetation models make logical assumptions about how carbon is cycled through plants. Each model thus represents a set of self-consistent hypotheses of carbon flows. Here seven state-of-the-art global vegetation models are used to investigate carbon turnover times and drivers across global forests, and are compared to the limited available large-scale observational constraints. The models are consistent with independent large-scale estimates of forest biomass and net primary productivity (NPP), but global mean biomass turnover times for the period 1985-2014 nonetheless vary by up to a factor of two between models, both globally and regionally. This range reflects the substantial uncertainties in NPP and biomass stocks, as well as the effects of non-equilibrium environmental forcing. Phenology, i.e. turnover of leaves, non-woody belowground carbon and reproductive material, emerges as an important driver of spatial variation in turnover, and is simulated to be particularly important in northern regions. Assumptions as to the fraction of carbon invested in phenological processes vary widely, however; models are able to achieve reasonable levels of biomass through either substantial phenological investment and relatively moderate rates of woody turnover through mortality, or through high investment in woody tissue, with high rates of woody turnover. The limited constraints on carbon turnover due to tree mortality rates mean that the correct strategy for any given region is unclear. The simulated rates of mortality-driven turnover are also highly spatially variable, both within and between models, reflecting the variety of mechanisms used to represent tree death. Conceptually grouping these mechanisms reveals very different hypotheses as to whether the dominant form of tree death in any given region is due to a physical disturbance (e.g. breakage, fire) or to tree vitality. These different hypotheses demonstrate the variety of ways in which current ecosystem state can be logically simulated in the absence of further constraints on the rates of tree mortality and phenological turnover at the large scale. Such differing hypotheses for present-day function are shown to propagate into very different projections under future environmental conditions. The challenge now is to gather observations that allow testing of these model hypotheses, knowledge which will be a crucial baseline for understanding how forest biomass turnover will

evolve under global environmental change. A perspective on the necessary observations is offered.