

## **Climate-related large-scale variation in forest carbon turnover rate - Evaluating global vegetation models using remote sensing products of biomass and NPP**

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Vegetation carbon turnover, in terms of its spatial variation and its response to climate change, is one of the most important, but also most uncertain carbon fluxes in terrestrial ecosystems. Its measurement is hardly possible by inventory studies alone, due to several reasons: First, vegetation carbon turnover involves a variety of processes, including litterfall, background mortality, and mortality by all kinds of disturbances, affecting single biomass compartments, individual trees or even whole ecosystems. Second, these processes act on very different timescales, involving short-term extreme events and long-term responses, and spatial scales, from local extremes to global impacts. In order to capture this variety of processes, spatial scales and timescales, here we estimate forest carbon turnover rate from novel remote sensing products of NPP and biomass. These products allow investigating the spatial variation in long-term mean turnover rate at  $0.5^\circ$  resolution across northern boreal and temperate forest ecosystems and its relation to climate variables. We observe an increase in turnover rate with colder and longer winters in boreal forests, whereas in temperate forests the spatial gradients in turnover rate are related to the length of both warm and dry periods. Thus, we hypothesize that the spatial variation in turnover rate can be explained by direct and indirect frost damage effects on mortality in boreal forests but drought and insect outbreaks in temperate forests. An evaluation of a set of global vegetation models (GVMs) participating in the Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP; including HYBRID4, JeDi, JULES, LPJml, ORCHIDEE, SDGVM, VISIT) shows that those models are able to reproduce the observation-based spatial relationships only to a limited extent. Deviations from the observation-based turnover rates can be mostly attributed to severe overestimations of biomass, however also important differences in the simulated spatial patterns in NPP become visible. These results highlight that the representations of mortality mechanisms in GVMs need to be improved in order to better match observed carbon stock spatial patterns and finally enable a better informed prediction of future land carbon cycle feedbacks to climate change. Current shortcomings are expected to lead to underestimation of climate change induced intensification in forest mortality and of the resulting positive feedback to climate change.