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Disequilibrium of terrestrial ecosystem CO_2 budget caused by disturbance-induced emissions and non-CO_2 carbon export flows: a global model assessment

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The global carbon budget of terrestrial ecosystems is chiefly determined by major flows of carbon dioxide (CO_2) such as photosynthesis and respiration, but various minor flows exert considerable influence by reducing carbon stocks and accelerating turnover. This study assessed the effects of eight minor carbon flows on the terrestrial carbon budget using a process-based model, the Vegetation Integrative SImulator for Trace gases (VISIT), which also included non-CO_2 carbon flows, such as CH4 and biogenic volatile organic compound (BVOC) emissions and subsurface carbon exports and disturbances such as biomass burning, land-use changes, and harvest activities. In the historical period of 1901–2016, the VISIT simulation indicated that the minor flows substantially influenced terrestrial carbon stocks, flows, and budgets. The simulations without and with minor flows estimated mean net ecosystem production in the 2000s as 3.04 $\pm$ 1.0 Pg C yr–1 and 4.94 $\pm$ 0.9 Pg C yr–1, respectively. Including minor carbon flows yielded an estimated net biome production of 2.19 $\pm$ 1.0 Pg C yr–1. Biomass burning, wood harvest, export of organic carbon by erosion, and BVOC emissions had impacts on the global terrestrial carbon budget amounting to around 1 Pg C yr–1 with specific interannual variability. After including the minor flows, ecosystem carbon storage was suppressed by about 280 Pg C, and its mean residence time was shortened by about 1.5 yr. The minor flows occur heterogeneously over the land, such that isoprene emission, subsurface export, and wood harvest occur mainly in the tropics and biomass burning occurs extensively in boreal forests. These minor flows differ in their decadal trends, due to differences in their driving factors. Aggregating the simulation results by cropland fraction and annual precipitation yielded more insight into the contributions of these minor flows to the terrestrial carbon budget. This study estimated uncertainties in the estimation of these flows through parameter ensemble simulations and sensitivity simulations, and the results have implications for observation, modeling, and synthesis of the global carbon cycle.