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Simulation of boreal forest carbon dynamics after stand-replacing fire disturbance: validation and model evaluation of a global vegetation model

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This study simulates boreal forest carbon dynamics after stand-replacing fire disturbance, using a process-based vegetation model called ORCHIDEE. The aim is to calibrate the forest stand structure, and carbon flux and carbon pools after fire disturbance. To achieve this aim, we used a new "forestry" module in ORCHIDEE which can explicitly represent forest structure and the process of self-thinning. Observations in three post-fire forest chronosequences in North America (Detla Junction in Alaska, Thompson in Manitoba, Canada and Albert in Saskathewan, Canada) were used as validation data. The validation variables include: stand density and mean diameter at breast height (DBH), annual GPP, NPP, NEP and ecosystem respiration, total biomass carbon (or above-ground biomass carbon), forest floor carbon, coarse woody debris (CWD) carbon, and mineral soil carbon. We chose a fire return interval of 160 years in the simulation. The model results generally compare well with the observation. Following a stand-replacing fire, (1) GPP and NPP increase steadily during forest regrowth until 30-40 years when the increase either stops or slows down. Slight decrease in GPP in the later growth stage occurs and NPP decreases more significantly. The heterotrophic respiration undergoes a surge immediately after burning and then remains relatively stable during the forest regrowth. Consequently, the net ecosystem production remains negative (the ecosystem being a CO_2 source for the atmosphere) for 20-30 years after fire, after which the forest begins to function as a CO_2 sink. This CO_2 sink peaks in the intermediate stage, and it is followed by a decrease again in later stages before the next disturbance event. Over the whole fire return interval, the net carbon exchange is mainly controlled by forest NPP. (2) The biomass carbon stock increases steadily after disturbance and then more slowly in later succession stages. Forest floor carbon (i.e. aboveground litter or soil organic carbon) stock and total coarse woody debris carbon pools (fire snag and downed dead wood) show a 'U' curve shape during the course of the forest regrowth, whereas mineral soil carbon remains relatively stable through time. In general, this study demonstrates that a global vegetation model as ORCHIDEE is able to capture the essential ecosystem processes and reach satisfactory results in both carbon fluxes and carbon stocks changes following stand replacing fires.