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Phenological Improvement and Evaluation of ELM Using the SPRUCE Observations

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Phenology transitions determine the timing of changes in land surface properties (e.g., albedo and roughness) and exchanges of biosphere-atmosphere materials (e.g., carbon, energy and water). However, current phenological processes for seasonal deciduous plant types in the land component of the US Department of Energy's (DOE) Energy Exascale Earth System Model (ELM of E3SM) are based solely on growing-degree-day (onset) and photoperiod (offset) models, and are thus unable to fully characterize the long-term phenological responses under changing environmental conditions. We introduced new phenology onset and offset models to seasonal-deciduous and evergreen forests, in which the timing of plant development depends on various environmental cues (forcing and chilling processes for onset, photoperiod and air temperature for offset). The revised models were evaluated and calibrated using the unique phenology observations (e.g., the PhenoCam) in the Spruce and Peatland Responses Under Climatic and Environmental Change experiment (SPRUCE) in northern Minnesota. The impacts of using the updated phenology algorithm on major land variables were also systematically examined. We found that the revised models better represent the phenology trends responding to different warming treatments for both ambient and elevated CO_2 levels. Moreover, the earlier onset and later offset in the revised model improved the simulation of evapotranspiration and water table during the growing season. The new phenology models provide improved predictive capacity for both leaf onset and offset in mixed spruce and larch forests in the Northern Hemisphere, and more importantly, induce significant effects on the terrestrial carbon and hydrological cycles. This new modeling effort also demonstrates the potential to enhance the E3SM representation of land-atmosphere feedbacks, especially under anticipated warming conditions when chilling might be insufficient and limit the spring onset advance.