Title: Modification and Evaluation of ELM Seasonal Deciduous Phenology Against the SPRUCE Observations

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Project Abstract: 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 model (onset) and a fixed daylength threshold (offset). Thus, they are limited in characterizing the long-term phenological responses under changing environmental conditions, causing large uncertainties in the prediction of land-atmosphere interaction. We introduced new phenology onset and offset models to seasonal-deciduous forest and shrub, respectively, in which the timing of plant development depends on various environmental cues (forcing and chilling processes for onset, and daylength and air temperature for offset). The modified models were calibrated and evaluated using the unique phenology observations (i.e., the PhenoCam) in the Spruce and Peatland Responses Under Climatic and Environmental Change experiment (SPRUCE) in northern Minnesota. Compared to the default phenology algorithms, the revised models were found to better represent the deciduous phenology for both deciduous forest and shrub, in terms of the timing magnitudes and phenological responses to different warming treatments, especially for autumn offset. Moreover, the updated ELM with revised phenology schemes generally produced higher land fluxes (e.g., GPP and evapotranspiration) than those simulated by the default ELM because of the lengthened growing season induced mainly by the later offset. This modeling effort also demonstrates the potential to enhance the E3SM representation of land-atmosphere feedbacks at broader spatial scales, especially under anticipated warming conditions when chilling might limit the rate of spring onset advance and offset may continue to delay.