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Landscape and climate controls on spatiotemporal patterns of European beech phenology tracked from Landsat data

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Phenology is a key indicator of vegetation response to global climate change, though our understanding of the underlying functional relationships is yet limited. Consequently, we aim at shedding light on the controls on the spatial and temporal patterns of European beech (*Fagus sylvatica*) phenology by utilizing a novel Landsat based hierarchical modeling approach. We test a variety of landscape and climate controls hypothesised to influence European beech green-up and senescence: 1) The effects of topography (i.e., elevation, slope, aspect, solar radiation) on spatial pattern of green-up and senescence. 2) The effects of spring temperature and winter chilling on temporal patterns of green-up. And 3) The effects of autumn temperature and precipitation on temporal patterns of senescence. Using a Landsat based approach allows us to tackle questions at the landscape-scale, while still covering a long enough time period of 30 years (1985-2015) for testing effects from regional-scale climate variability. Preliminary results indicate strong spatial and temporal variation in phenology. Spatial variation in green-up and senescence is driven by local scale topographic variation, in particular elevation (-2.0 d^{-100m}). Temporal variation indicates a substantial trend towards earlier green-up (-1.0 d$^{-1yr.}$) and later senescence (+1.6 d$^{-1yr.}$), resulting in an overall longer vegetation period (+2.6 d$^{-1yr.}$). Temporal variation in green-up was mostly influenced by regional-scale variations in pre-season minimum temperature (-3.7 d$^{-1^{\circ}C}$), though we found only limited evidence for winter chilling effects. Temporal variation in senescence correlated with minimum autumn temperature (+5.0 d$^{-1^{\circ}C}$) and precipitation (+2.0 d^{-10mm}). Overall season length was controlled by annual mean season temperature with an average increase of +18.0 d$^{-1^{\circ}C}$. We also found that those controls were moderated by topography, with higher elevation areas being more sensitive to changes in temperature. Our Landsat based approach allows for assessing the spatial and temporal patterns of *Fagus sylvatica* phenology and the underlying controls at spatial and temporal scales yet hardly explored by the phenological community. As such, our approach will help refining process-based models of vegetation phenology, which in turn will improve prediction of vegetation response to global climate change