Assessing the influence of local phenology on the response of forest productivity to changes in growing season length

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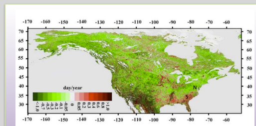
Introduction

A trend towards a longer growing season has been observed in regional- to global-scale remote sensing time-series spanning the past 30 years. Our research aims to develop a mechanistic understanding of the relationship between remotely observed variability in local phenology, growing-season stability and carbon uptake by forest ecosystems. At local- to regional-scales, variability in site characteristics (e.g. stand age, density of understory canopy, micro climate, availability of belowground resources) are likely to determine the extent to which a longer growing season influences net carbon uptake and tree productivity. Methods for measuring phenology from medium-resolution data have recently been developed, offering the potential to test hypotheses regarding phenology-ecosystem relationships using the 30-year multi-scale remote sensing record of canopy greenness and structure. However, such work requires a 30-year record of ecosystem processes that is easily, and relatively inexpensively, scaled from trees to forest stands, thus enabling assessment of ecosystem responses to variations in phenology over broad spatial extents. We are using tree-ring growth and $\delta^{13}C$ and $\delta^{15}N$ to meet this challenge.

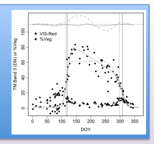
Objectives

1. *Assess the influence of environmental factors on medium-resolution spatial patterns in the spring onset, growing-season stability, and autumn offset of greenness.*
2. *Determine how change in the timing of spring onset, recorded by coarse-resolution sensors, has influenced forest productivity across gradients in medium-resolution phenology and growing- season greenness stability.*

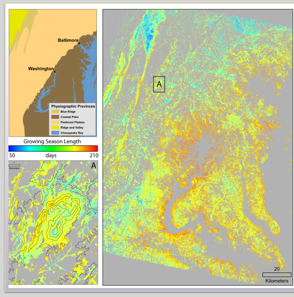
Concept development



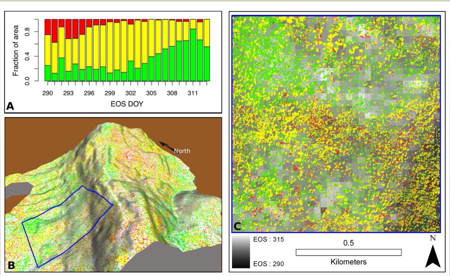
Depiction of advancing or delayed onset of spring greenness (from Zhang et al 2007). We intend to utilize this variability at the Capital Region National Parks (N) and the Great Smoky Mountain National Parks (S) to explore phenological drivers of the productivity of trees.



We measure within-region average phenology using dense stacks of Landsat data orgainized by DOY.

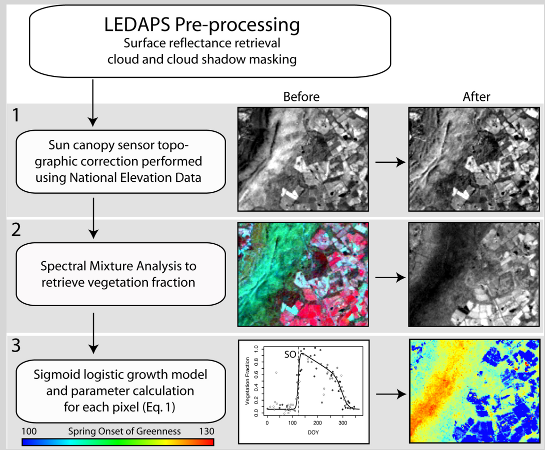


Within region variation in the phenology of greenness is significant, and driven by landscape factors such as distance to urban areas, distance to tidal water, and elevation. At the largest scales, average phenology varies with species composition and micro-topography.



Comparison with a high resolution autumn air photo showing (A) that red and yellow canopies are associated with early greenness offset (EOS), (B) considerable spatial variability in autumn color, and (C) spatial coherence between canopy color and autumn greenness offset. Previous work by Fisher et al. (2006) validated a similar approach for measuring phenology from Landsat against field observations of leaf emergence.

Landsat processing stream

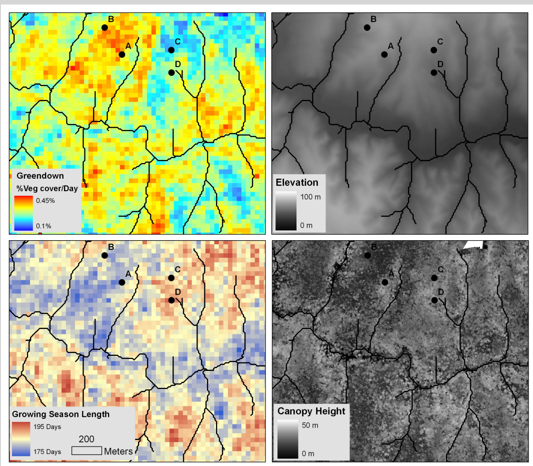


Equation 1: m_1 and m_2 describe the minimum and amplitude of vegetation greenness (v), m_3 and m_5 are the spring onset and autumn offset of greenness, and m_4 and m_6 are the rates of change in spring and autumn.

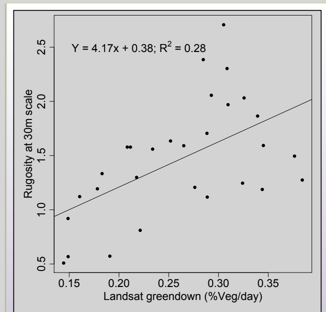
$$v(t,\mathbf{m}) = m_1 + (m_2 - m_7 \cdot t)\left(\frac{1}{1+e^{(m_3'-t)/m_4'}} - \frac{1}{1+e^{(m_5'-t)/m_6'}}\right)$$

Site selection

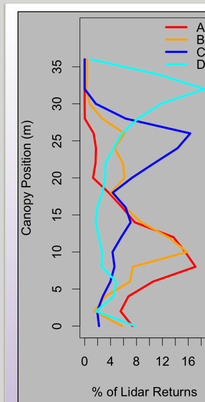
Sites within each study region are selected for tree coring to maximize variation in greendown and growing season length (left panels), and topography and canopy height (right panels; both from discrete return LiDAR. The four locations (A-D) are sites in Prince William Forest National Park (in northern VA) with tree-ring and canopy structure data shown to the right.



Preliminary results

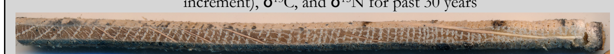


The relationship between the standard deviation of canopy height (rugosity) and the average summer greenness greendown from Landsat for 29 forested plots at Prince William Forest Park.



LiDAR canopy profiles for the 4 sites shown to the bottom left at Prince William Forest Park.

Tree cores of white oak, red oak, and tulip poplar measured for BAI (basal area increment), $\delta^{13}C$, and $\delta^{15}N$ for past 30 years

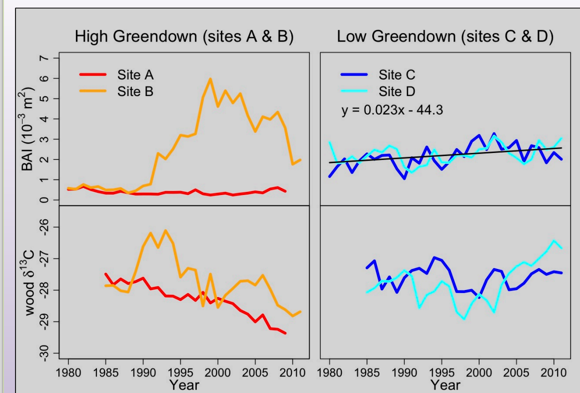


$$\delta^{13}C_{leaf} = \delta^{13}C_{atm} - a - (b-a)\frac{C_i}{C_a}$$

Intrinsic water use efficiency (photosynthesis/transpiration) and $\delta^{13}C$ are both controlled by C_i

$\delta^{15}N$ of plant tissues has been shown to correlate with plant nitrogen availability.

We hypothesize that tree response to a longer growing season depends on site characteristics, such that sites with access to soil moisture and N throughout the growing season (as assessed by $\delta^{13}C$ and $\delta^{15}N$) will increase productivity as a result of a longer growing season.



Only at low greendown sites (C & D) did we observe a trend towards increased productivity. Prior to 1990, high greendown sites exhibited reduced productivity relative to low greendown sites. However, in ~1990 BAI at site B increased.