Phenological implications of sequential 2020 spring freezes for deciduous forests of the Interior East, USA

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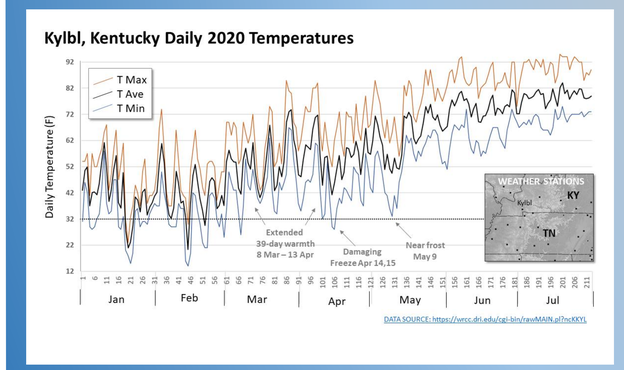
2020's "false spring"

Warming winters may increase the likelihood of spring freezes that disrupt forest phenology. Forest species are known to vary in their frost sensitivity, yet little is known of how that biological vulnerability relates to local topographic factors. Microclimatic impacts have been associated with both lower slope sites affected by cold air drainage and higher elevations that are more likely to freeze later in the spring, despite greening up later. This research compares phenological behavior as tracked by NDVI time series during two successive freeze events using high frequency 250m MODIS satellite imagery and high resolution 10m Sentinel 2 imagery. A freeze in mid-April 2020 resulted in widespread damage to freshly emerged leaves across Tennessee and Kentucky in lower and mid slope positions, but the cold spared the canopy of upper slopes. A month later, sub-freezing cold struck forests of West Virginia, Virginia and Kentucky, impacting ridgeline forests well into summer. Percent phenological progression maps quantify the status and track subsequent recovery. These maps contextualize the site-specific phenological timing of the freeze, which suggests vulnerability. That local phenological status, as much as the species present, is likely important for understanding freeze responses such as the persistence of NDVI impacts into the growing season. Microclimate vulnerability shifted over the course of the spring to include at first lower slopes, then upper slopes. A similar local response was observed during hard freezes during the earlier-than-normal springs of 2007 and 2012 in the region, and together, these four freeze events suggest commonalities and differences. Patterned vegetation NDVI responses to spring cold suggest that the hazard from freezes with a warming climate will likely be mediated by local topographic and vegetational factors in complex ways.

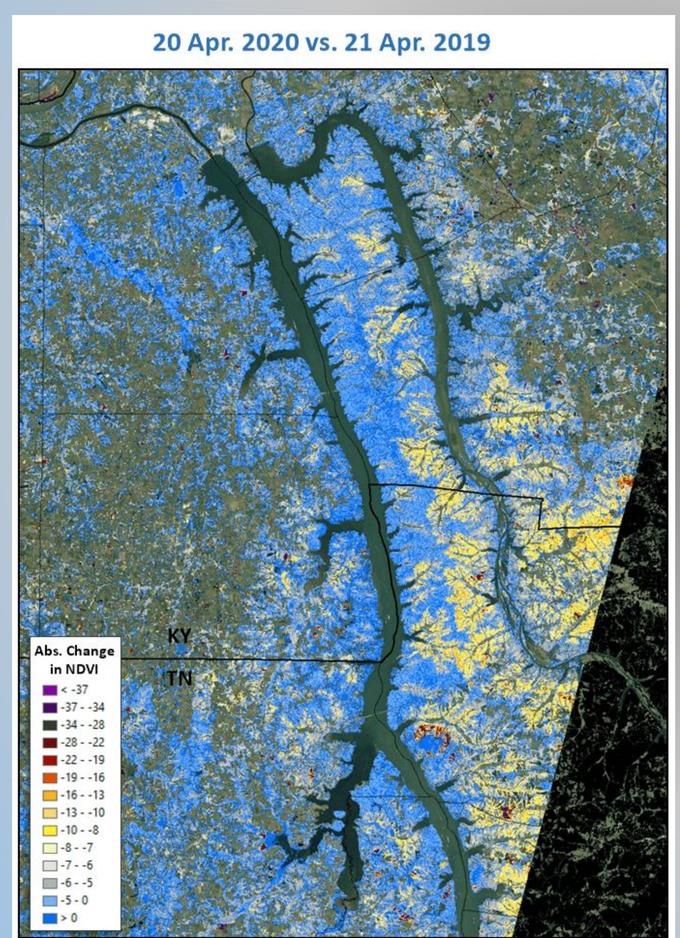
Mid-April frost damage was widespread across Kentucky and Tennessee. Lower slope damage reflects cold air drainage. Credit: US Forest Service.



Seasonal weather included unusually long warm during March and early April 2020 (a period lasting 5 weeks) which was then followed by a freeze. This was a longer warm period than in the epic early April 2007 hard freeze (Gu and others 2008, Bioscience) but that freeze reached lower minimum temperatures.

Topographic patterns of warmth followed by cold at Land-Between-The-Lakes, KY

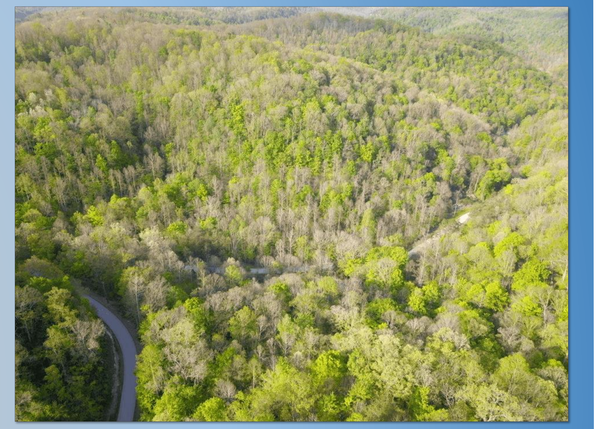
Change in NDVI from Sentinel 2 satellite imagery mapped using Google Earth Engine and dates one year apart indicate that lower forested slopes experienced a setback while upper forest slopes continued to progress. Change was addressed using the HiForm.org workflow.



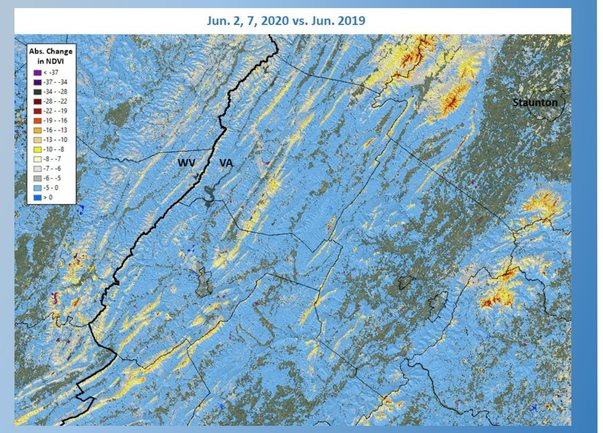
The topographic patterns resolved by Sentinel 2 at Land Between The Lakes were consistent with aerial observations (above). Field observations of canopy damage and shriveled leaves confirmed damage from freezing temperatures below). This extended to several different tree species. Credit: US Forest Service.

Patterns of species vulnerability and phenological implications

In eastern Kentucky and Virginia, a second May 9-10, 2020 freeze caused additional damage beyond that of mid April. This impacted tulip poplar and sycamore, in particular. Credit: Abe Nielson, Kentucky Div. Forestry.



Given their slower green-up due to altitudinal effects, high elevation mountain forests of western Virginia and West Virginia experienced frost differently. It delayed phenology overall.



The implications of spring freezes after periods of warmth depend on many local factors including two topographic factors: cold air drainage and altitude. Also important are stand-level species composition and the actual timing of the frost event relative to this years' phenology. Double freezes are possible, but their effects remain poorly understood. This complexity makes freeze impacts hard to understand and predict as temperatures warm.