Mountain wave-induced extreme wildfire behavior

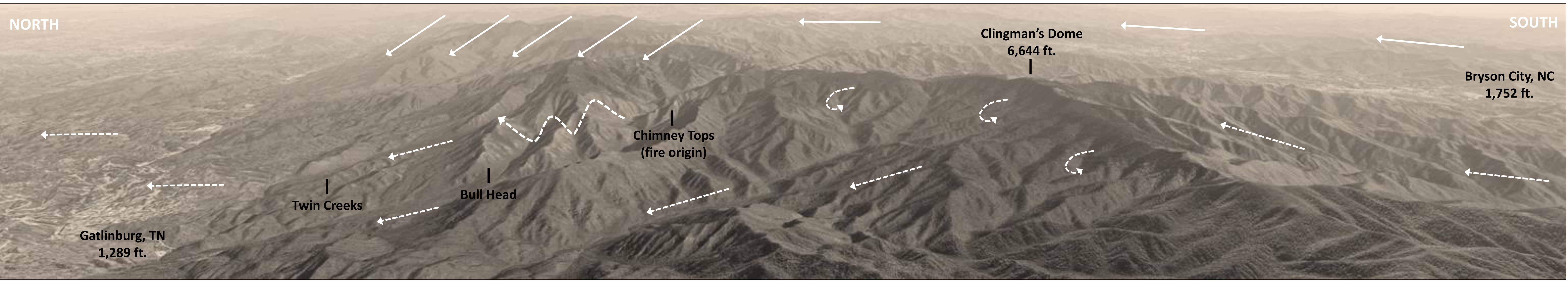
The deadly eastern Tennessee fires of 2016

Steve Norman, William Christie, William Hargrove

US Forest Service Southern Research Station, Asheville NC 28801

steve.norman@usda.gov
william.m.christie@usda.gov
william.w.hargrove@usda.gov

Table mountain pine, key indicators of historical intense fire behavior, rise above Gatlinburg after the 2016 fire.

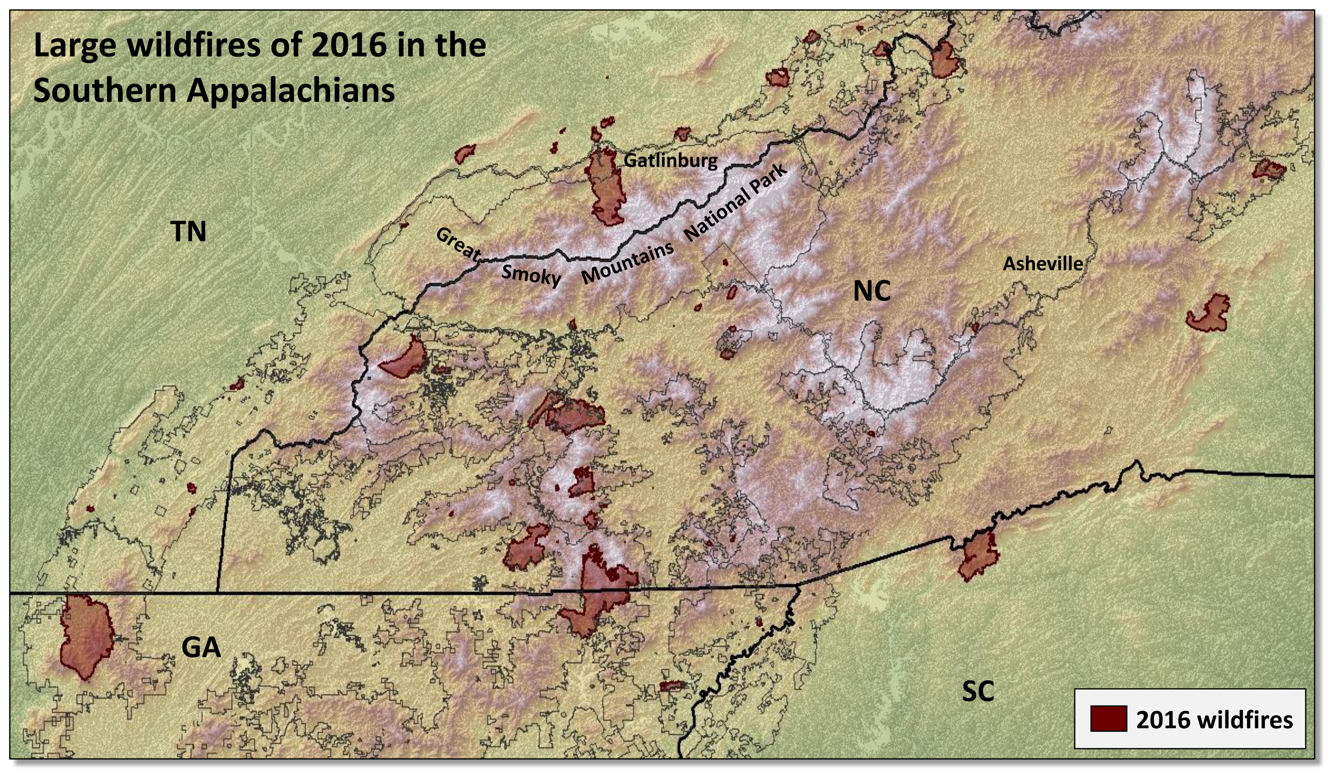


AN EXTREME WILDFIRE SEASON

In the fall of 2016, an extreme warm drought raised fire hazards across the Southern Appalachians. Abnormally dry conditions were accompanied by a rash of accidental and deliberate ignitions that resulted in over a dozen large fires that scarred over 130,000 acres of federal, state and private forests. On federal lands, more area burned during the fall 2016 fire season in the Southern Appalachians than during all other fall fire seasons combined since 1970. The season-ending event of Nov. 28, 2016 was a 17,000 acre fire complex that burned Great Smoky Mountains National Park, Gatlinburg and surrounding communities. These fires led to the loss of 14 lives and around 2,500 structures. The surprisingly extreme fire behavior observed during this event was facilitated by the drought, the historically high and seasonal fuels, and sustained hurricane-force winds.

Since 2016's record fire season and the extreme fire behavior and community losses that occurred, planners want to better understand the region's risk of extreme fire. Concerns are heightened by predictions of more frequent drought and more extensive development in coming decades.

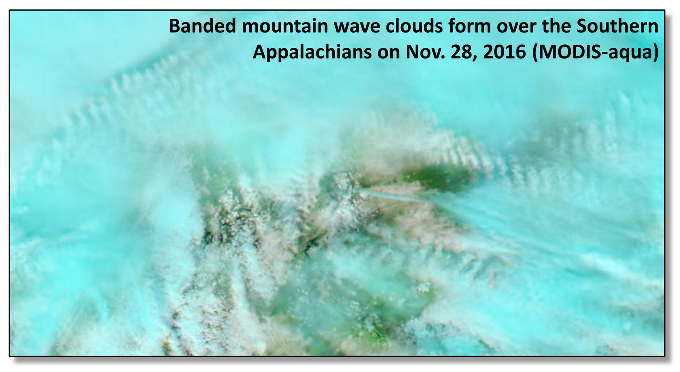
Soon after the firestorm, a mountain wave was implicated as a contributing factor. This research addresses landscape aspects of that weather hazard to further insight into extreme wildfire risks within the region.



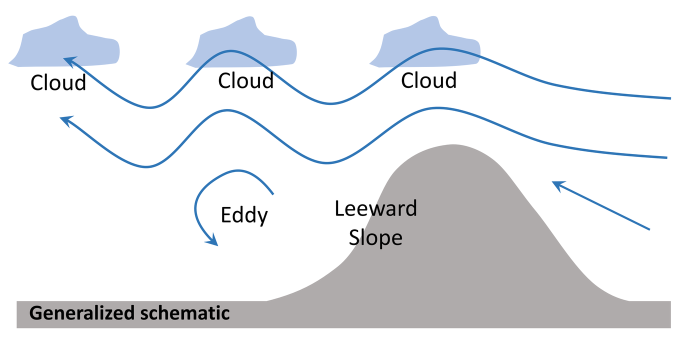
WHAT IS A MOUNTAIN WAVE?

Mountain waves form when stable air passes over a range causing local turbulence and gravitational effects on the leeward slope. Much like stream water dips in the lee of a boulder, gravity-fed winds and erratic eddy flow are characteristics of this phenomenon. Mountain waves have been repeatedly observed in the foothills of the Great Smoky Mountains where the high elevation and orientation of the range, its steep leeward north slope, and the enhancing effects of the landscape structure of the surrounding Blue Ridge mountains and valleys are contributing factors. During a mountain wave event, sustained winds can exceed 90 mph and cause severe damage to infrastructure (D. Gaffin, 2009, Weather and Forecasting, 24:5-75).

The requisite stable air is largely confined to the non-summer months in this region. As a cold front approaches from the west, strong south winds flow over the range with a veering wind profile (winds shift to more westerly flow aloft). Such conditions recur multiple times each year between Sep. and May, though only a fraction occur during periods of extreme fire hazard. Adiabatic warming associated with these downslope winds may also increase fire hazards.

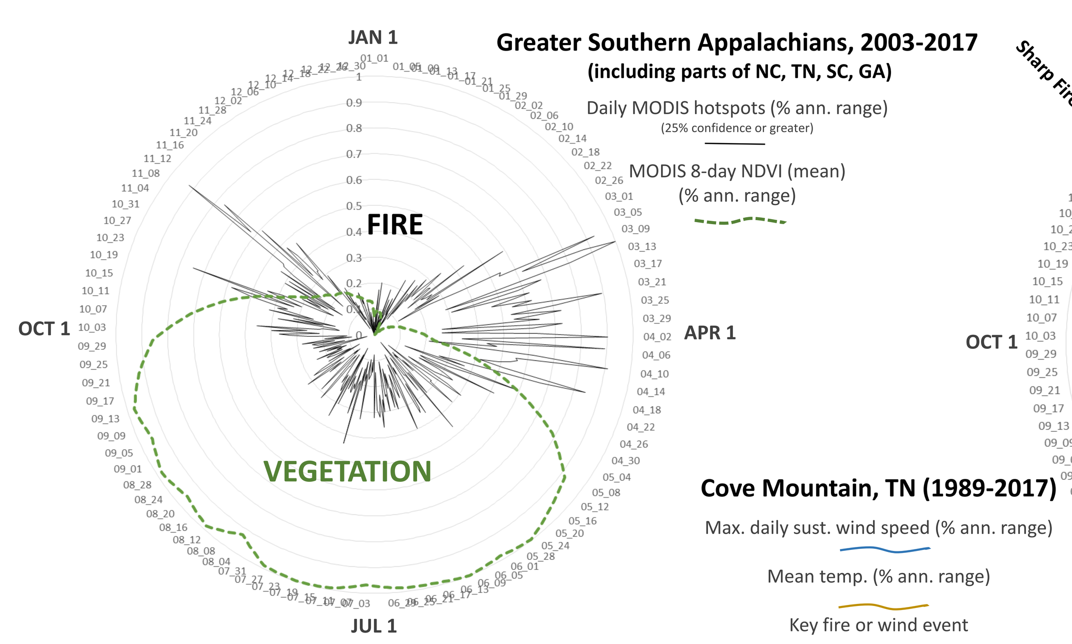


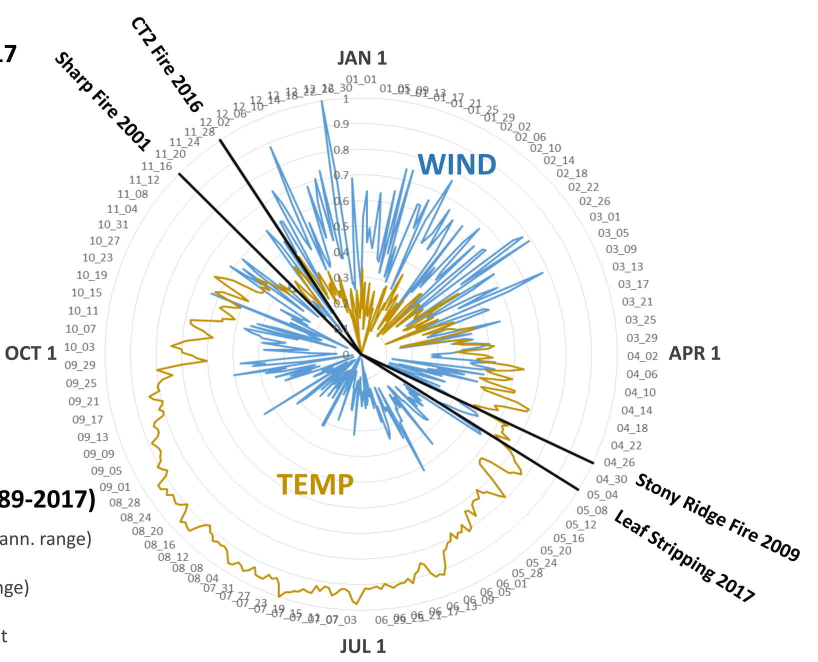
Banded mountain wave clouds form over the Southern Appalachians on Nov. 28, 2016 (MODIS-aqua)



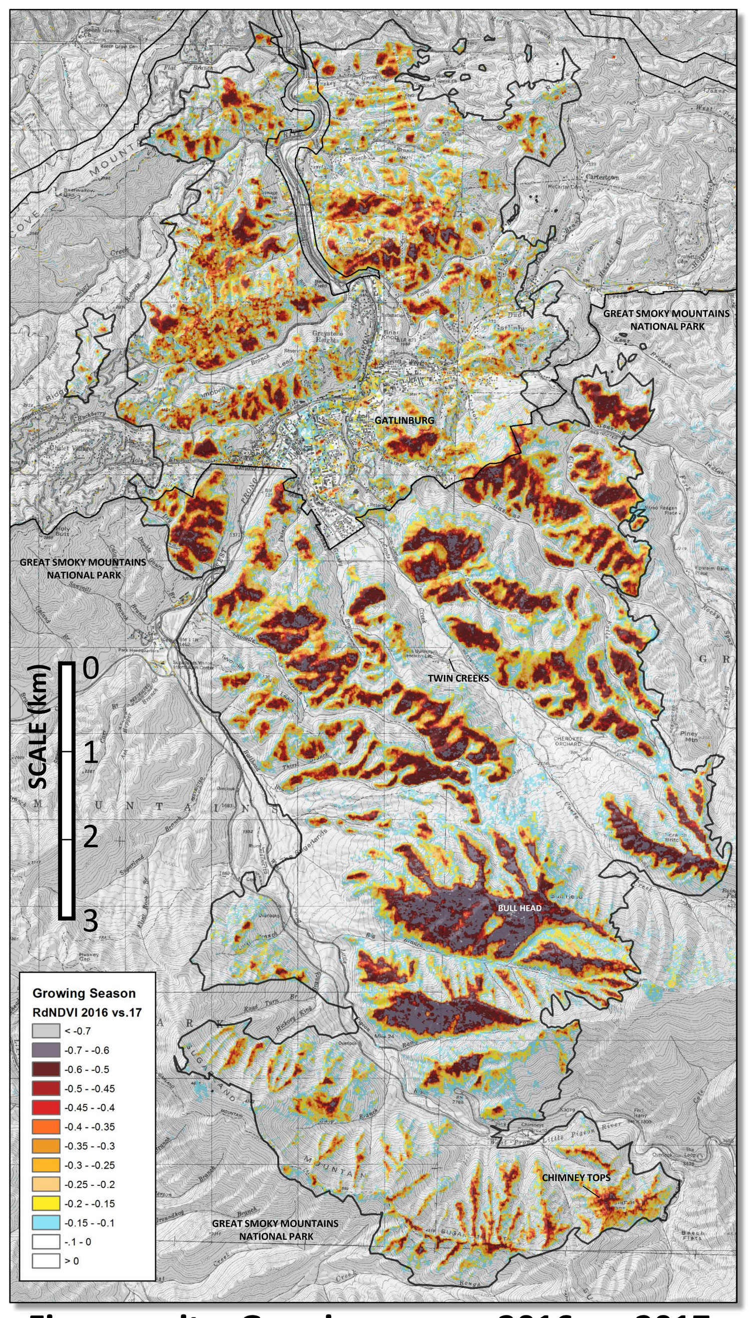
Generalized schematic

THE SEASONALITY OF APPALACHIAN FIRE





Southern Appalachian wildland fire is strongly seasonal, with peaks in both spring and fall (left). Fire mostly burns in mid to late spring prior to green-up, then, though less regularly, returns in November after the annual leaf fall has replenished surface fuels. During summer, the season with maximum heat, there is much less fire than before or after, and this pattern can be explained by the reduced winds and higher humidity of summer that partially depend on vegetation phenology. The combination of high wind, freshly fallen seasonal fuels, and the low humidity and high temperature during fall drought put the 2016 fire season in context.



Fire severity: Growing season 2016 vs. 2017 (above); lost homes near Gatlinburg (below).

MAPPING MOUNTAIN WAVE HAZARDS

Landscape exposure to mountain wave-winds is difficult to describe because terrain and turbulence make winds locally erratic and weather stations are scattered. While damage is an indirect measure that is affected by other factors, changes caused by disturbances can provide critical clues about exposure and help validate models. With this research, we compare two types of damage from sequential mountain wave events: the Nov. 28, 2016 fire storm and a May 4, 2017 wind event using change in NDVI at 10m resolution from Sentinel 2 satellite imagery.

Patterns of vegetation severity after fire show strong correspondence with topography, with south aspects being particularly vulnerable to lethal fire. These dry sites are dominated by serotinous table mountain pine with a resprouting mountain laurel understory. This vegetation and observed fire effects suggest the existence of a long-standing site adaptation to extreme fire. The meteorologically similar May 2017 windstorm largely resulted in leaf stripping with impacts extending across the foothills. At 10m, there is clear evidence of channelized wind flow and differences in impacts by aspect both within and outside the burn area.

The Mountain Wave wildfire

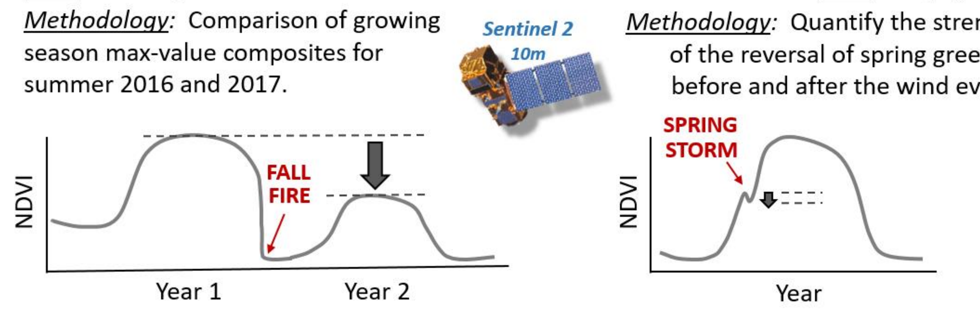
Date: Nov. 28, 2016

Methodology: Comparison of growing season max-value composites for summer 2016 and 2017.

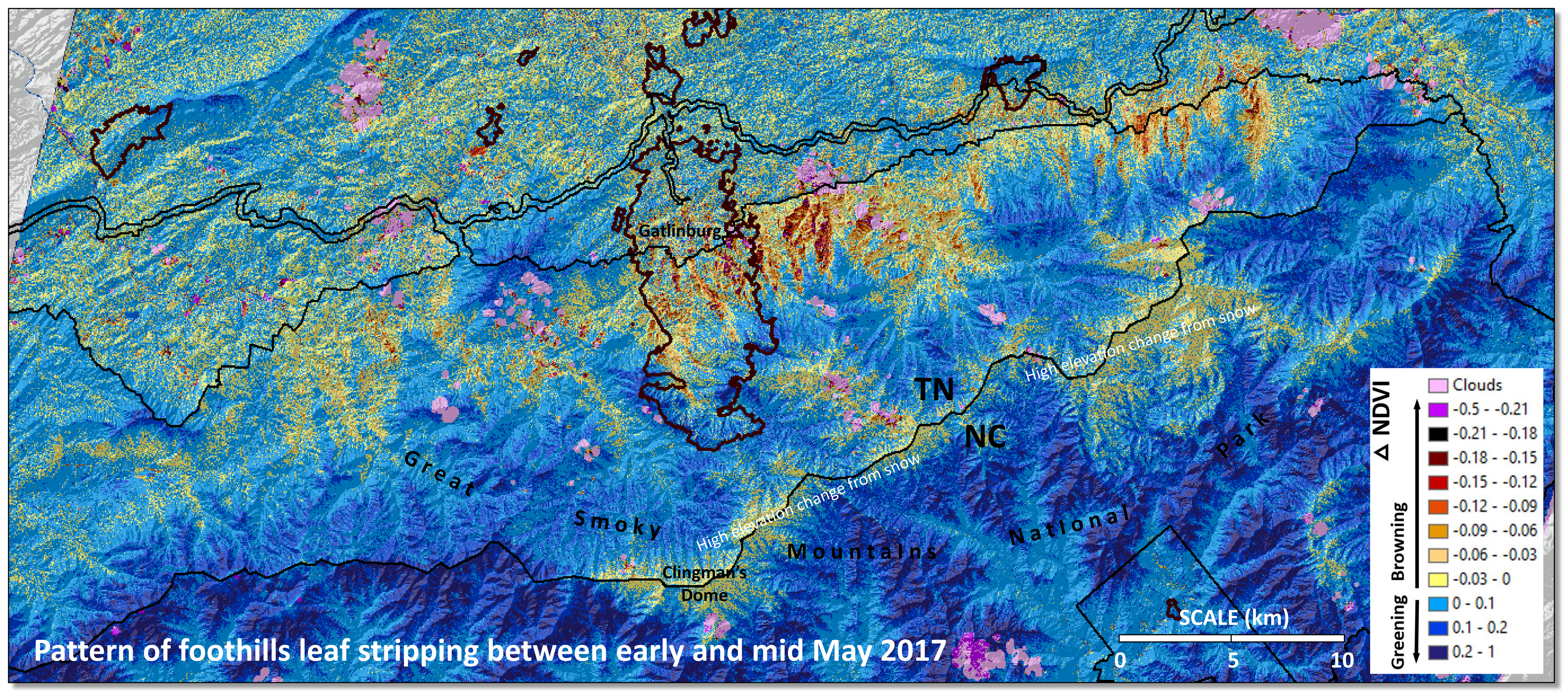
The Mountain Wave windstorm

Date: May 4, 2017

Methodology: Quantify the strength of the reversal of spring greenup before and after the wind event.



These two manifestations of this mountain wave dynamic reveal the particularly high exposure of these foothills to extreme weather.



Pattern of foothills leaf stripping between early and mid May 2017

COMMUNITIES AT SPECIAL RISK

Wind-driven fire that can threaten communities can occur in spring or fall across the Southern Appalachians, yet extreme mountain wave-associated hazards are localized within the region due to topography. The Great Smoky Mountains foothills are particularly vulnerable to recurrent mountain waves, and as much as these events occur during the fire season, they comprise an endemic and recurrent hazard. The predicted increase in drought frequency and storm intensities over coming decades suggests that mountain wave fire associated hazards may also increase.

Risks to communities are increasing due to the rapid development of this landscape (see graphs at right). Sevier County's population has more than tripled since 1970, with a great increase in resident and non-resident homes (in 2016, a majority of losses were non-resident rentals and second homes). The turbulent wind and ember rain that characterized the 2016 Sevier County wildfires meant that homes across topographic positions were readily lost, and most property owners have already rebuilt on the same footprint.