**A Plant’s Life: Mapping Heat Accumulation Over Time at NEON’s Terrestrial Field Sites in Relation to Deciduous Broadleaf Tree Phenology**

Plants make up 80 percent of the total carbon content of all living things on the planet, with land plants being the most notable. We rely on plants for many things: transforming the carbon dioxide we emit into oxygen we breathe, providing us with food and resources, shading us on hot summer days, and helping with flood control, to name a few. Plants are also the basis of all the beautiful landscapes around the world for us to appreciate. Not only can looking at plants be enjoyable but observing the way plants look can also be very useful to us for many reasons.

*Plant Phenology Importance*

Plant phenology is the transition of plants through phenophases, or observable stages of their life cycle that have a defined starting and ending point. Examining how plant phenology changes over time, especially in relation to temperature and heat accumulation, is important to humans in: optimizing when to plant, fertilize, and harvest crops; managing invasive species; predicting human health-related events like the timing and severity of allergies; understanding the timing of ecosystem processes, such as carbon-cycling; and assessing the vulnerability of species and ecological communities to ongoing climate change.

(picture from NEON aquatic site with canopy cover over a stream or algae bloom)

(picture of NEON DBL tree from a field site?)

(image of a gypsy moth? Or icon from <https://www.neonscience.org/data/data-themes/organisms-populations-communities>

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Invasive species are usually better at adapting to fluctuating climates than native species, so while native species may be affected negatively by earlier springs, invasive species are more likely to dominate in their habitat. By being able to predict when springs will likely start using phenology data over time, controlling invasive species in an area would be easier, which can help regulate the whole ecosystem.

For example, the gypsy moth is an invasive species that primarily feeds on the leaves of deciduous broadleaf trees­–trees known for their habitat dominance and importance to their ecosystem food web. When the gypsy moths invade and feed on the leaves of these trees, competition between other organisms that rely on these leaves increases, which can possibly lead to decreases in survival rates of certain species, causing other effects within the food web. When too many leaves are consumed, the ecohydrology and local weather in the area may be affected by the loss of the canopy.

With less canopy coverage over water sources, increased algae blooms may occur due to exposure to more sunlight. This can negatively affect the whole aquatic ecosystem as other organisms in the water that need sunlight can’t get it due to the abundance of algae, leading to a decrease in food supply for aquatic animals and creating a domino effect within the aquatic food web. When the time comes for the leaves of these trees to fall, which supplies a source of carbon to the microbes in the soil that are important regulators of the carbon cycle, but there are no leaves to fall, then important ecosystem cycles are affected.

Leaves are only one phenophase that are observed in plants. What about flowers, which we all love to admire and smell? If flowering plants don’t flower when other organisms expect them to, then pollinators that rely on these flowers may have to find other sources of pollen, and when the time comes for these flowers to be pollinated, the pollinators may have moved on, leaving the plants to rely on other ways of pollinating. Each phenophase that is observed in plants are important to systems and organisms at different times.

Maybe a map of the US with NEON sites that have DBL trees marked

*Plant Phenophases*

NEON has been collecting data on [plant phenology](https://data.neonscience.org/data-product-view?dpCode=DP1.10055.001) at NEON terrestrial sites across the United States since late 2013. Part of the data follows deciduous broadleaf trees as they change through their breaking leaf buds, increasing leaf size, leaves, colored leaves, open flowers, and falling leaves phenophases. NEON employs status-based monitoring in which the phenological condition of an individual is reported any time that individual is observed. Status and intensity data are reported per phenophase per individual or patch, for each day observed.

Images of DBL individuals in each of the phenophases

*Impact of Temperature on Phenology*

Plant phenology is highly affected by temperature. High temperatures, for example, may cause non-perennial crops to develop more quickly and have a shorter life cycle, resulting in smaller plants, shorter reproductive duration, and lower yield potential. Along with high temperatures comes earlier springs. When springs occur earlier, plants are more susceptible to freezes that can come after the beginning of false springs, especially when the plants have already started to transition to their next phenophase, leading to negative long-term effects on the plant.

Perennial crops may also be affected, if temperature shifts affect the chilling requirements of fruit or nut production. Chilling requirements are related to heat requirements. If the winter is long and cold, then less warmth is needed in the spring to bring most plants out of dormancy. But when the winter is warm, plants need more warmth in the spring to prompt leaf growth. When many woody plants are not exposed to cold temperatures in the winter to reach their chilling requirement, then delays in leaf-out may follow.

Timelapse of plant phenology images????

[Air temperature data](https://data.neonscience.org/data-product-view?dpCode=DP1.00002.001) is also collected at NEON field sites using Single Aspirated Air Temperature (SAAT) assemblies on deployed towers. With air temperature data, growing degree days can be calculated, which link temperature and its effect on plant phenology. Growing degree days (GDDs) are the number of degrees the average daily temperature exceeds the temperature below which the organism will remain developmentally inactive.

For many plants, a specific number of growing degree days must accumulate to trigger a change in phenological status. This minimum number of GDDs is referred to as a plant’s growing degree threshold. If a growing degree threshold for a phenological transition is known for a particular organism, it is possible to investigate how soon that transition is likely to be reached by calculating accumulated growing degree days (AGDDs) over the course of a year.

By mapping this heat accumulation in the form of AGDDs days and comparing it to the transitions in phenophases for deciduous broadleaf trees, the relation between the two can be observed, and by comparing across years and NEON field sites, it is possible to make predictions for changes in the climate and changes in phenology in years to come using the data.

Shiny app

*The Future of Phenology and AGDDs*

While the Observatory continues to collect phenology and air temperature data over the course of 30 years, it may be possible to make better predictions for future seasonal changes with a larger dataset. These predictions can then help us in controlling parts of the food web and ecosystems that may be affected negatively by a changing climate over time.

Observing changes in plants is important, but AGDDs affect other organisms as well. With evidence supporting the green wave hypothesis, which states that migrating herbivores should track the leading edge of green-up, where forage quality is the highest, then changes in the timing of green-up may lead to changes in patterns in their migration or eating habits and could be detrimental in their ability to adapt to the changes. Climate change can also lead to phenological mismatches in mutualistic interactions between plants and animals. With phenological shifts in plants happening sooner or later than shifts in animals that usually occur at the same time, the interactions between these organisms may be much briefer, which may end their mutualistic relationship altogether.

It may be interesting to observe how AGDDs are affecting other organisms and species without relying on plant phenology data to see how relations between similar transitions throughout the life cycles of these organisms is affected by heat accumulation as well. With the transition of NEON sensors in the water sources at NEON aquatic sites to measure water temperature rather than just air temperature, it may also be interesting to observe how AGDDs in water temperature affect aquatic ecosystems.