GLOBE Educator One-Week Pacing Guide: *Plant Phenology*

Phenomenon: Plant Phenology **Grade Level:** 4-8	**Guiding Question:** How are plants, land cover, and climate related?	**Contact:** Reach out to Brian Campbell (brian.a.campbell@nasa.gov), if you have questions.
Further Investigation: Trees Around the GLOBE Student Research Campaign		
Optional: Become a GLOBE Trained Teacher: GLOBE Biosphere Protocol Training		
Access GLOBE Pacing Guides: https://www.globe.gov/web/nasa-langley-research-center/home/resources		
Revision Date: 2-27-2022		

Standards - These standards are supported by the activities in this guide but not completely covered.		
Elementary	**Performance Expectations:** ● 4-ESS2-2 Analyze and interpret data from maps to describe patterns of Earth's features. ● 5-ESS3-1 Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.	**Disciplinary Core Ideas:** ● ESS2.B Plate Tectonics and large-Scale System Interactions ● ESS3.C Human Impacts on Earth Systems
	Science and Engineering Practices: ● Analyzing and Interpreting Data ● Obtaining, Evaluating and Communicating Information	**Crosscutting Concepts:** ● Patterns ● Systems and System Models

This work was supported by GLOBE Mission Earth, award No. NNX16AC54A, in collaboration with NASA Earth Science Education Collaborative.

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<table>
<tr><td rowspan="2">Middle</td><td>Performance Expectations:
MS-ESS2-1 Develop a model to describe the cycling of Earth’s materials and the flow of energy that drives this process.
MS-ESS2-2 Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.
MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
MS-LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms
MS-LS1-6 Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.</td><td>Disciplinary Core Ideas:
ESS2.A Earth’s Materials and Systems
ESS2.C The Roles of Water in Earth’s Surface Processes
ESS3.C Human Impacts on Earth Systems
LS1.C Organization for Matter and Energy Flow in Organisms
PS3.D Energy in Chemical Processes and Everyday Life</td></tr>
<tr><td>Science and Engineering Practices:
Constructing Explanations and Designing Solutions</td><td>Crosscutting Concepts:
Cause and Effect
Energy and Matter
Scale Proportion and Quantity</td></tr>
</table>

Background Information and NASA Connection

Phenology can be defined as the study of cyclic biological events and seasonal natural phenomena, especially in relation to climate, plant and animal life, such as flowering, breeding, and migration. Phenological patterns and processes can vary greatly across a range of spatial and temporal scales, and can provide insights about ecological processes like invasive species encroachment, drought, wildlife habitat, and wildfire potential. All of us have observed phenology in some way or another, including seeing the color of leaves changing, the growth of trees during one season versus another season, the greening and browning of grass in the spring/summer and fall winter, respectively.

One way we can really see phenological change is to observe tree height and land cover in your local environment, over time. To look at both tree height and land cover over time is to take observations during each season, sometimes several times a season.

Tree height is the most widely used indicator of an ecosystem's ability to grow trees, so tracking tree height over time can help us to assess the ecological health of a given area. Changes in trees and tree height are greatly affected by the changing climate, with a tie-in to a changing land cover. Changes in land cover are important because land cover can alter temperatures and rainfall patterns. Some types of land cover absorb carbon from the atmosphere, and when subject to changes, such as a forest burned in a wildfire, result in more carbon entering the atmosphere.

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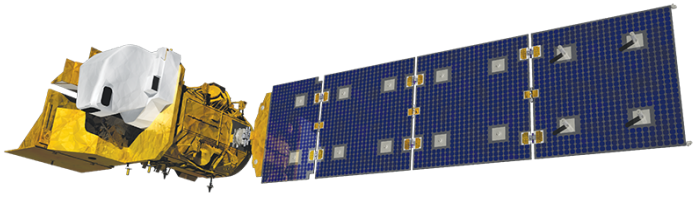
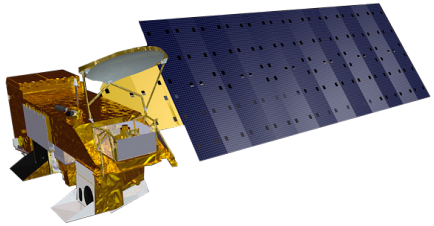
Our planet's climate is changing dramatically and we no longer have the same climate conditions we had 50 or 100 years ago. This can impact growing seasons, and in turn, when, where and how we farm crops for food. With this information, we need to really look closely at the local phenological changes so that we can understand what is happening globally and how trees and land cover respond to a changing climate.

You can learn more about the science of phenology at https://www.globe.gov/web/phenology-and-climate/overview/science-background.

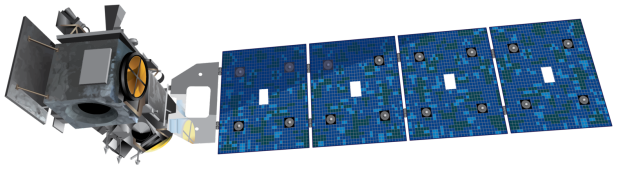
We don't just observe phenological changes from the ground. NASA satellites, instruments, and sensors can be used for monitoring global phenology patterns and looking at change over time. Missions like Landsat 9, Terra MODIS, ICESat-2, GEDI, and others view the Earth synoptically and allow researchers to see global scale phenological changes through remote sensing techniques.



Landsat 9



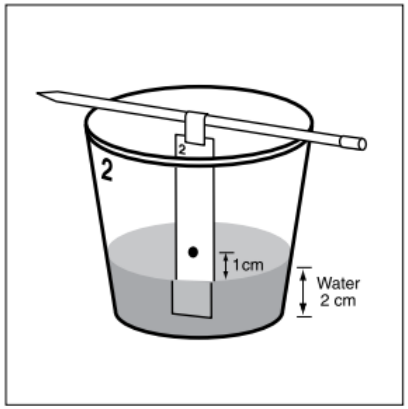
Terra MODIS



ICESat-2

While the satellites deployed by NASA and worldwide space agencies give us a big picture of what's happening on Earth, they struggle at times to provide a detailed analysis of what's happening in specific locations. That's why it's so crucial for researchers to have ground truth data gathered from the Earth's surface. The GLOBE Program is NASA's largest and longest lasting citizen science program about the Earth. Through the program's GLOBE Observer app, you can contribute to our current state of scientific knowledge while filling society's growing need for informed citizens and trained professionals in future generations.

Activities		Assessment Options
Day 1: Tree Growth Game **Materials:** Listed in activity	 Image Credit: My Tree	Completed tree posters. ***Connection to guiding question:*** *What does a tree need to grow?* ***Answer:*** *Water, carbon, soil, sunlight.*

Activities		Assessment Options
Day 2: Investigating Leaf Pigments Exploration 2 beginning on page 4. Note: Instructors will want to prepare samples to be used prior to the class period. **Materials:** Listed in activity	 Image Credit: Investigating Leaf Pigments	Experiment rubric on page 6 of the activity. ● What can be inferred from the presence of the dominant color present on the strip. *Answer: Chlorophyll is the main photosynthetic pigment usually present in high quantities in green leaves. Other pigments may dominate when chlorophyll levels decrease.* ● What can you infer from the fact that there are different pigments in leaves? *Answer: These can be seen when the chlorophyll decreases, and is why leaves change color.* ***Connection to guiding question:*** *When do chlorophyll pigments typically decrease?* ***Answer:*** *During green down or during the fall season.*

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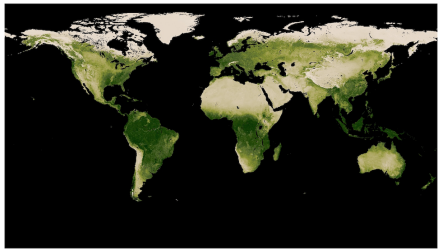
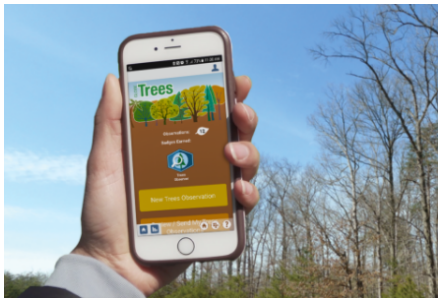
<table>
<tr><th colspan="2">Activities</th><th>Assessment Options</th></tr>
<tr><td>Day 3: Observing Annual Vegetation Changes

Materials: Online activity</td><td> 
Image Credit: NASA Earth Observations (NEO)</td><td>Understand that there are seasonal changes.

Connection to guiding question: How would the visualizations look different if there were large losses of vegetation for an area?
Answer: There would be less green up and green down, or change in the vegetation.

Connection to guiding question: What could cause large losses of vegetation in an area?
Answer: Answers may include: deforestation, fires, landslides, volcanoes, climate and landcover changes.</td></tr>
<tr><td rowspan="2">Day 4: GLOBE Observations
● The GLOBE Program’s GLOBE Observer Tree Height and/or Land Cover Tools
● If you are not using the GLOBE Observer tools, you may use the following protocols.
○ Biometry Including Tree Height
○ Land Cover Classification

Materials: Online activity

Only make observations if you can do so safely and legally.</td><td rowspan="2">  </td><td>Develop consensus as a class and discuss observations.

Connection to guiding question: Does the area around your tree have many other trees? What does this indicate about the land cover?
Answer: Answers will vary.</td></tr>
<tr><td>Optional Instructional Videos:
● GLOBE Observer Trees Introduction
● How to Take a NASA GO Tree Observation
● GLOBE Observer: Land Cover - Getting Started</td></tr>
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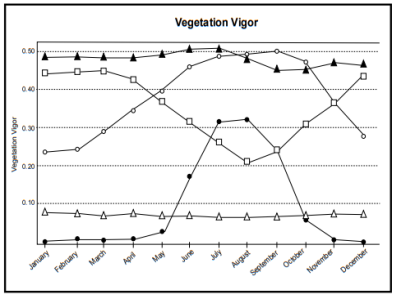
Activities		Assessment Options
Day 5: Global Patterns in Green Up and Green Down Page 9 **Materials:** Listed in activity.		Questions from activity. ***Connection to guiding question:*** *Do you think changing climate (temperatures and/or precipitation) would have an impact on plant growth?* ***Answer****: Changes in climate can impact the timing of seasonal changes and cause the green up and green down to happen at different times.* ***Connection to NASA:*** *How and why would NASA study trees and landcover?* ***Answer:*** *NASA can detect changes in tree height and landcover over time. This can give us information on how the planet is changing over time including changes in the timing of seasons shown by changes in plant phenology or green up and green down.*

Additional Resources		
Online Activities	Audience	Description
Mission Biomes	Ages 9-14	Investigate different biomes and test your knowledge.
Identifying Changes in Land Use	Middle and High School	My NASA Data mini lesson. Learn how Landsat data are used to detect changes in land use. This video describes how the data are interpreted and gives examples of changes in forests.

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Additional Resources		
Hands-On Activities	Audience	Description
Green Up Cards	All	This activity is to prepare students to recognize what a bud looks like and the progression of green-up from the time of budburst. Students will arrange plant growth pictures taken from the bud, shrub canopy, grass clump, landscape and regional perspectives.
A Sneak Peek at Budburst	Elementary and Middle School	Students will do simple explorations to observe the relationship between budburst and temperature. This is a winter or dry season activity to be done prior to green-up observations.
An Alaskan Mystery: A GLOBE Data Exploration	Middle and High School	Students analyze data about the timing of budburst for a tree species over three years in the same location. They investigate two different hypotheses for why timing differs by analyzing weather data from the same time period.
A Beginning Look at Photosynthesis	Elementary and Middle School	Simple investigation to see how plants respond to light.
First Look at Phenology	Elementary and Middle School	Observe, compare and classify plants during green up or green down and make inferences based on patterns observed.
Tree Health Check-up	All	Just like people can be healthy or sick, so can trees! Experts who study trees (called arborists) look for symptoms in trees to determine whether they are healthy or not. In this activity, learners will look for some of these indicators in a tree nearby.
Hands-On Activities	Audience	Description
Budburst Buddies Storybook	Elementary	Follow the story of Lily and Sage and they learn what stories plants can tell from making observations about what plant parts they can see, then use the observation sheets go outside and make your own observations to become a Budburst Buddy. This is especially fun in the spring, when you can find the first leaves and flowers.

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Additional Resources		
Hands-On Activities	Audience	Description
My NASA Data: How can a series of Landsat images help scientists estimate a forest's age over time?	Middle School	This activity is modified from the USDA/US Forest Services' lesson found in the Natural Inquirer newsletter. The purpose of this hands-on activity is to engage students in a similar process for monitoring forests as NASA scientists use to study the Biosphere, whereby they apply what they know of human aging (i.e., the appearance of gray hair's on heads) to the change of forests over time.
Mount Saint Helens Volcano	Middle and High School	This investigation provides an overview of the local effects of volcanism. Students categorize causes, effects, and responses to volcanic hazards by focusing on the interdependence of all Earth systems. Using various remotely-sensed images, students observe the visible effects of the eruption of Mount St. Helens in 1980 over time. Based on these observations, students identify a buffer zone to designate safer locations for development.
Videos and Reading	Audience	Description
Why Observe Tree Height?	All	*Why Observe?: Tree Height* explores surface height measurement missions and the role that citizen science can play within the scientific community.
Breaking Down the big Questions at NASA	All	Brian Campbell describes how to answer a big question by breaking it down into smaller questions.
Greening Up Globally: Forests and Farms	Ages 9-14	This Earth Observer Kids (eoKids) issue talks about green up, forests and farms.

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