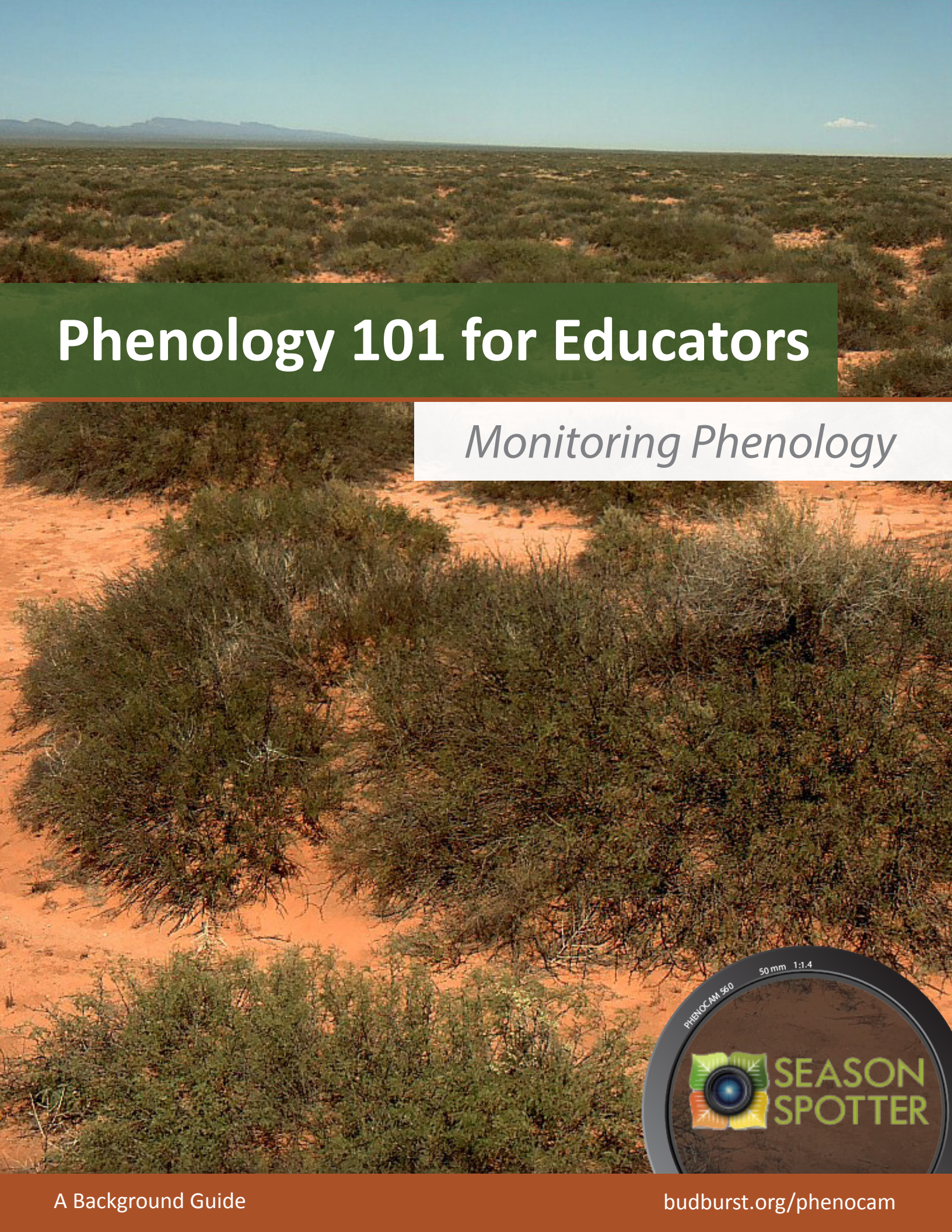
Phenology 101 for Educators

Monitoring Phenology



A Background Guide

budburst.org/phenocam

Monitoring Phenology

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HARVARD UNIVERSITY

Project BudBurst™ Timing is everything!

SEASON SPOTTER

Welcome to Monitoring Phenology

If you are interested in tracking one plant over time, you can focus on that plant by looking at it from ground level. If you wanted to track a larger group of plants (maybe even a forest), you would need a different perspective. Think of the difference in what you would see in plants from a fire tower, high above a forest as compared to walking on a trail in that same forest. In plant phenology, both perspectives are important. And whether you are collecting observations on the ground or over a large area, both yield useful data - different scales, different perspectives. As with much of science, it really depends on what you are trying to learn.

How do data sets collected (and analyzed) at different scales compare? Through a new partnership with The PhenoCam Network (more on that later in the guide), participants can explore plant phenology from different perspectives. This new partnership has resulted in the creation of Season Spotter, an online crowdsourcing project that engages individuals in the actual annotation and categorization of PhenoCam images. Don't know what remote sensing is? Don't worry - you will know more after working through this guide!

How to Use this Guide

This guide contains a combination of readings, discussions, activities, and a self-assessment.

You will find the necessary background content needed to utilize the suite of ala carte educational resources including PowerPoint, hands-on activities, and videos.

Helpful Hints:
- The first instance of each glossary word in the text is italicized
- Full URL's for links can be found in the Appendix on page 14

Learning Objectives

- Be able to explain the basic principles associated with remote sensing phenology
- Be able to describe the strengths and limitations of plant phenology data collected at different scales
- Become familiar with The PhenoCam Network
- Be able to categorize and annotate remotely sensed plant phenology imagery through participation in Season Spotter

Time Commitment

The anticipated time commitment for completing this unit is, on average, 1.5 – 2.5 hours.

Readings	30 min – 1 hr
Classify images	30 min
Activities	30 min – 1 hr

What You'll Do

✓ Learn about remote sensing phenology

✓ Learn about a plant phenology citizen science project, Project BudBurst

✓ Explore plant phenology observations near you

✓ Classify PhenoCam images through SeasonSpotter

As part of a National Science Foundation Macrosystems Biology grant EF-1065074 to the PhenoCam Network, NEON's Project BudBurst is making these resources freely available for use by educators. Please visit the PhenoCam website to learn more.

How do we Monitor Phenology?

Phenology at Different Scales

Whether carefully studying changes in individual plants or looking at large scale plant community change from above the ground, both observational scales tell us more about how plants respond to the climate. The use of data collected from cameras, satellites, and airplanes to track phenology is known as "*remote sensing phenology*" and can complement phenological observations on the ground. Remote sensing systems can detect broadscale events such as the onset of spring, known as *green-up* - when forests leaf out and grasses change from brown to green. Remote sensing systems can also detect the onset of autumn, known as *brown-down*, when the leaves fall and the grasses turn brown.

Check it out...

Watch the National Ecological Observatory Network's video on Scaling Phenology

It's important to remember that phenologic observations using remote sensing data often tell us different stories than observations made on the ground (e.g., Project BudBurst observations). For example, remote sensing data can be used to view green-up and brown-down events over broad areas such as throughout the entire state of Colorado or the globe.

However, it is more challenging to use remote sensing data to understand phenophase timing for individual species or further identify/understand biologically important phenomena such as when flowers are most abundant, when fruits are ripe and when leaves are fully unfolded. For example, spring time green-up of grasses as seen from remote sensing imagery is not of high enough resolution to detect specific Project BudBurst grass phenophase events such as the appearance of early flowers or first ripe fruits.

Want to learn even more? Visit the USGS website on remote sensing phenology

Figure 1 - Measuring phenology at different scales. From left to right: *Citizen scientists* observing a plant; a camera taking continuous images of a forest; and a sattelite taking remote sensing images from space.

Observing on the Ground

Project BudBurst

Project BudBurst participants make careful observations of when plants leaf, flower, and fruit and share the observations with others. Scientists working with Project BudBurst have identified over 250 targeted plant species that include a variety of wildflowers, trees, shrubs, and grasses. These species were selected for broad geographic representation and accessibility. To date, Project BudBurst has had over 20,000 participants submit their plant observations from across the country.

Project BudBurst℠
Timing is everything!

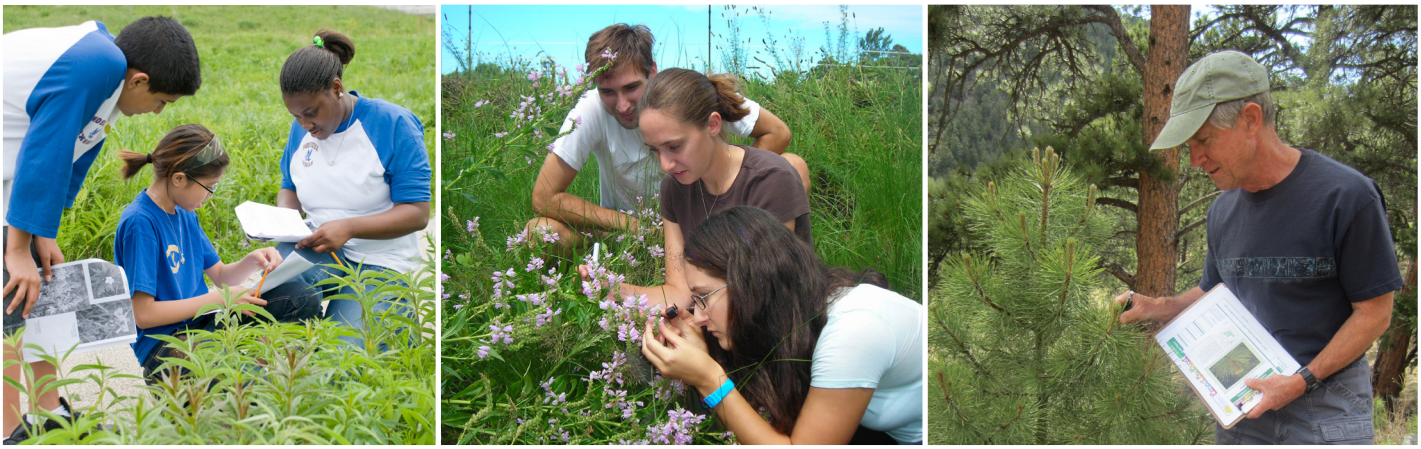


Figure 2 - People from all walks of life participate in Project BudBurst, a national *citizen science* plant phenology project.

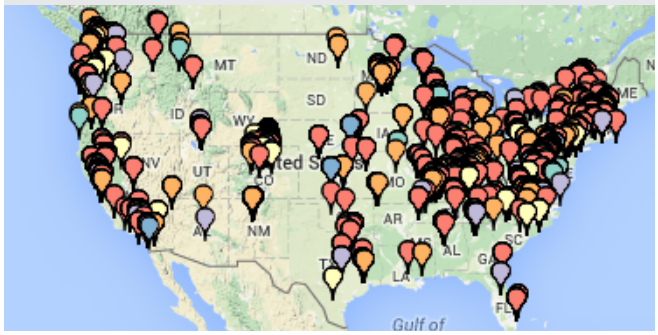
Participating in Project BudBurst can be an empowering experience as it allows individuals to contribute to a greater understanding of how our natural world responds to changes in the environment. Participants are able to learn about scientific processes through hands-on experience. Involvement in Project BudBurst gives individuals valuable experience in the importance of what goes into collecting data and gives them the opportunity to make meaningful contributions to ongoing scientific research. Project BudBurst data are freely available for anyone to download and use for noncommercial use.

To join the Project BudBurst community and submit your own plant observations, simply go online to budburst.org. Everything you need to participate can be found online.

budburst.org

Activity 1
Are there Project BudBurst observations near you?

Go the the Data tab on the Project BudBurst website (budburst.org) to view a data map. What types of observations have been submitted for your area? *Note: Don't forget to change the data map year to view past observations!*



Remote Sensing with Cameras

The PhenoCam Network

To measure more plants over larger areas, we need to view the forest above the trees at a different scale. Imagine what our human eyes would see standing in a tree-house looking across the top of a forest of trees. From this view we can see lots of trees, but maybe not each individual bud and leaf on each tree. We can capture that tree house view using cameras designed for tracking phenology - known as pheno-cams. Pheno-cams are placed in fixed locations and are programmed to take pictures of specific areas, every day. This spares us humans from having to man the tree house day and night recording what we see!

Figure 3 - PhenoCams from around the United States, from top to bottom: tundra (Fairbanks, AK); croplands (Lamont, OK); and mixed forest (Bangor, ME).

Pheno-cams record whether a plant is green or brown just like our eyes do. But a camera can take a picture of a whole lot of plants at one time, allowing us to estimate phenophase events across huge areas including entire sections of forests and grasslands. A camera records the amount of green or brown being reflected from those plants too - something our eyes can see but not assign a numeric value to. So as plants turn green in the spring, the amount and brightness of "green" in the image increases. And when plant leaves turn brown in the fall, the camera will records that too. If we plot the amount of green on a graph every day, we can tell when the trees begin to turn green. We can also record when the plants were the most green - also known as peak greeness. We can also tell and when they begin to turn brown, and when they lose their leaves or die back for the winter. Over time, we can compare the dates of peak greenness and browning leaves, to see if the dates change significantly from year to year.

What if we could get cameras mounted on tree houses across the country constantly taking pictures and automatically sending the pictures to a central database? That is pretty much what the PhenoCam Network does. However, instead of taking over tree houses, cameras are mounted on towers and platforms.

The PhenoCam Network is a cooperative network that archives and distributes the imagery from digitial cameras taken at research sites across North America. The cameras are mounted on towers and platforms and take pictures of different vegetated landscapes including forests, grasslands, and croplands. These automated cameras are on duty around the clock and all year long. The resulting images provide a unique record of how plants respond to seasonal change including the timing of leafing, flowering, and fruiting – the science of plant *phenology*. The PhenoCam Network takes plant phenology to a whole new level – literally! By placing cameras on towers and platforms, we really can see the forest for the trees and gain a valuable perspective on phenological change at the landscape scale.

Introduction to Season Spotter

As noted in the previous reading, many of the images from the PhenoCam Network are automatically classified or categorized by computers using algorithms developed to detect change in the greenness of vegetated landscapes. Generally speaking, computers and humans do a good job classifying images of seasonal transition dates (e.g. the start of spring green-up). It makes good sense to use computers to automate this type of classification given the large number of images needing classification. However, it turns out that computers are not as good at identifying phenological transitions such as flowering or fruiting, or that might be more abstract or subjective in nature (e.g., "intensity" of autumn colors). But humans are very good at this type of classification.

The PhenoCam Network partnered with Project BudBurst to create a new citizen science effort – Season Spotter. Utilizing a new platform on Zooniverse, a web platform for crowdsourced citizen science projects, Season Spotter was designed to engage individuals in making more in-depth image classifications that are beyond a computer's current capacity. This engaging new project asks people of all ages to view PhenoCam images and answer a few simple questions about each one. The answers to these simple questions in turn help the PhenoCam team improve the computer program that analyzes the images. Be careful, classifying these phenological images can be addicting!

seasonspotter.org

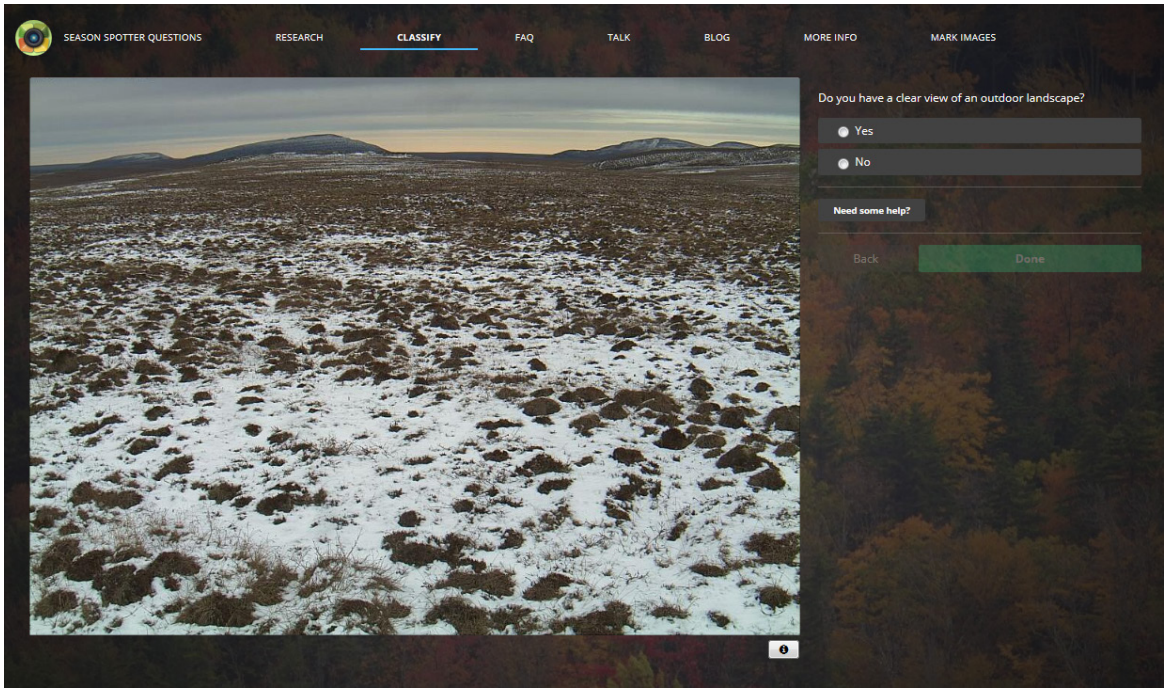


Figure 4 - Screenshot of the Season Spotter interface. Participants are present with an image from the PhenoCam Network then annotate the image or answer a series of questions. This information helps the PhenoCam team improve their computer program for analyzing images.

Activity 2
Classify PhenoCam Images

Classify two (or more!) images on seasonspotter.org. You can choose either of the two ways to classify: answer multiple choice questions OR answers questions and mark features. At the end of each set of questions, you should see a summary screen (see image below).

Q1. Did you decide to classify or mark images?

Q2. Did you find classifying/marking the images easy or difficult? Why?

Q3. How might the questions you were asked and/or features you were asked to mark while classifying relate to how the PhenoCam computer program calculates greeness?

A brief discussion of how the PhenoCam Network and Season Spotter might be used as a part of a lesson or discussion in your classroom or informal educational setting.

Combining Phenology Datasets

Using Ground Observations to Confirm Remote Sensing Data

You already know that Project BudBurst data are collected from ground observations all across the country. We know these data are very useful, however, as with any data, they have limitations. Think of the possibilities of combining Project BudBurst data with other datasets that cover equally large areas -- but from a different perspective. Combining Project BudBurst data with other broad-scale datasets allows scientists to look at "bigger picture" issues such as the influence of a changing climate and changing landuse on vegetation and wildlife. Broadscale, also known as remote sensing, data are commonly used for these types of analyses given they often cover wider areas.

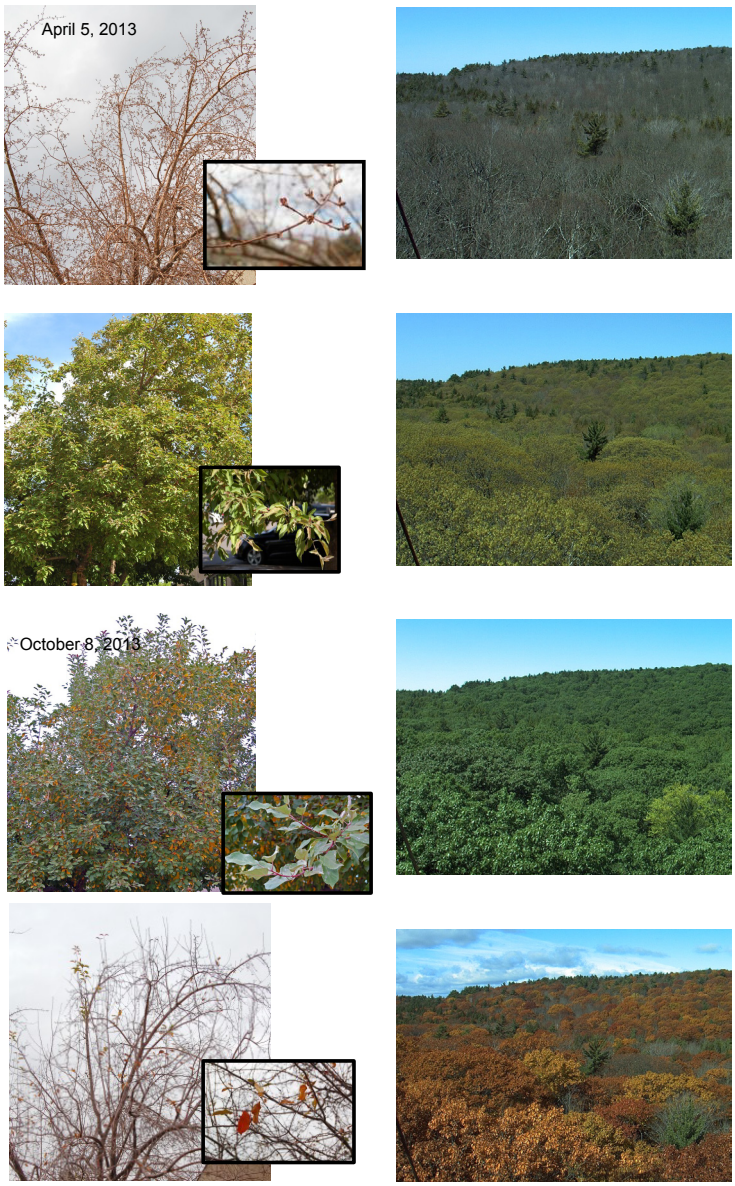


Figure 5 - Left: Ground observations. Right: Corresponding PhenoCam images.

Learn and Explore...

Want to learn more? Check out NEON's remote sensing ecology blog.

The blog contains more information about the relationship between on the ground measurements (including Project BudBurst observations) as compared to remote sensing measurements.

Because remote sensing data are collected from afar, how do we know if our data are accurate? "*Ground-truthing*" efforts, where participants use on-the-ground measurements to verify remote sensing data, can help ensure accurate interpretation of remote sensing data. Scientists, and citizen-scientists alike, can assist with ground-truthing efforts by contributing phenological observations to national programs like Project BudBurst!

Self Assessment

1. Remote sensing data can be used to track changes in vegetation "health" or greenness.

   True

   False

2. Season Spotter engages individuals in

   a. determining the exact date when all plants flower.

   b. classification of remotely sensed images of vegetated landscapes

   c. detection of landscape/features that are abstract or subjective in nature

   d. b and c

3. Remote sensing data can be used to track changes in vegetation conditions over broad areas, over time.

   True

   False

4. Remote sensing phenology is

   a. Alien tracking of changes in vegetation from space.

   b. Talking about phenology with others using remote stereo receivers.

   c. The use of data collected from satellites or airplanes to track vegetation phenology.

5. In comparison to the human eye, computers are always better for image classification.

   True

   False

6. Project BudBurst is an online citizen science program that does not require any special training for participation and all information needed to participate can be found on the website (budburst.org).

   True

   False

Answer Key

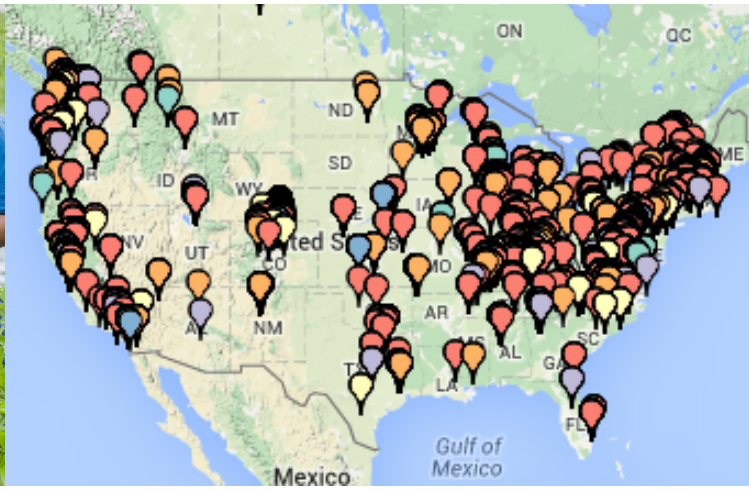
1. True 2. d 3. True 4. c 5. False 6. True

Monitoring Phenology

Review and Glossary

This background guide introduced you to the science of remote sensing plant phenology and the importance of observing plants as indicators of changes to climate and the environment. We also discussed the PhenoCam Network, a network of cameras which allow participants to explore plant phenology from different perspectives. The new partnership with PhenoCam and Project BudBurst has resulted in the creation of Season Spotter, an online crowdsourcing project that engages individuals in the actual annotation and categorization of PhenoCam images.

We hope this guide got you thinking about how data sets collected (and analyzed) at different scales compare and how you might present this new information to your learners when using plant phenology data in your educational setting.



Next up...

- Explore the supplementary *Monitoring Phenology* resources (Student activities, videos, etc.).
- Get started on the next unit, *Introduction to Phenology Data*.

Review and Glossary

Links from this Unit

PhenoCam Network: http://phenocam.sr.unh.edu/webcam/

National Ecological Observatory Network's video on Scaling Phenology: https://youtu.be/_4uHLXL1yZA

USGS website on remote sensing phenology: http://phenology.cr.usgs.gov/overview.php

Project BudBurst: http://www.budburst.org/

Project BudBurst Data Map: http://budburst.org/results

Season Spotter: http://seasonspotter.org

National Ecological Observatory Network's remote sensing ecology blog: http://www.neonnotes.org/2012/06/reflections-on-remote-sensing-ecology-and-the-neon-aop/

Google Chrome: https://www.google.com/intl/en/chrome/browser/

Internet Explorer: http://windows.microsoft.com/en-us/internet-explorer/download-ie

Firefox: http://www.mozilla.org/en-US/firefox/new/

Glossary

Definitions of technical terms used in this unit. Glossary definitions have been compiled from the Project BudBurst, USA National Phenology Network, SciStarter and NOAA websites.

Citizen science: the public involvement in inquiry and discovery of new scientific knowledge. A citizen science project can involve one person or millions of people collaborating towards a common goal. Typically, public involvement is in data collection, analysis, or reporting.

Citizen scientist: an individual who voluntarily contributes his or her time, effort, and resources toward scientific research in collaboration with professional scientists or alone.

Brown-down: Phenophase events that generally occur in the fall and are often associated with plants preparing for the winter dormant period.

Green-up: Phenophase events that generally occur in the spring time and are often associated with a plant emerging from a winter dormant period, when limited or no growth occurs.

Ground-truthing: The use of ground measurements to verify remote sensing data. Ground-truthing is done to help ensure accurate interpretation of remote sensing data.

Phenology: Phenology refers to recurring plant and animal life cycle stages. It is also the study of these recurring plant and animal life cycle stages, especially their timing and relationships with weather and climate.

Phenophase: An observable stage or phase in the annual life cycle of a plant or animal that can be defined by a start and end point. Phenophases generally have a duration of a few days or weeks. Examples include the period over which newly emerging leaves are visible, or the period over which open flowers are present on a plant.

Remote sensing: the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites.

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budburst.org/phenocam

A collaboration between NEON Citizen Science and the PhenoCam Network.