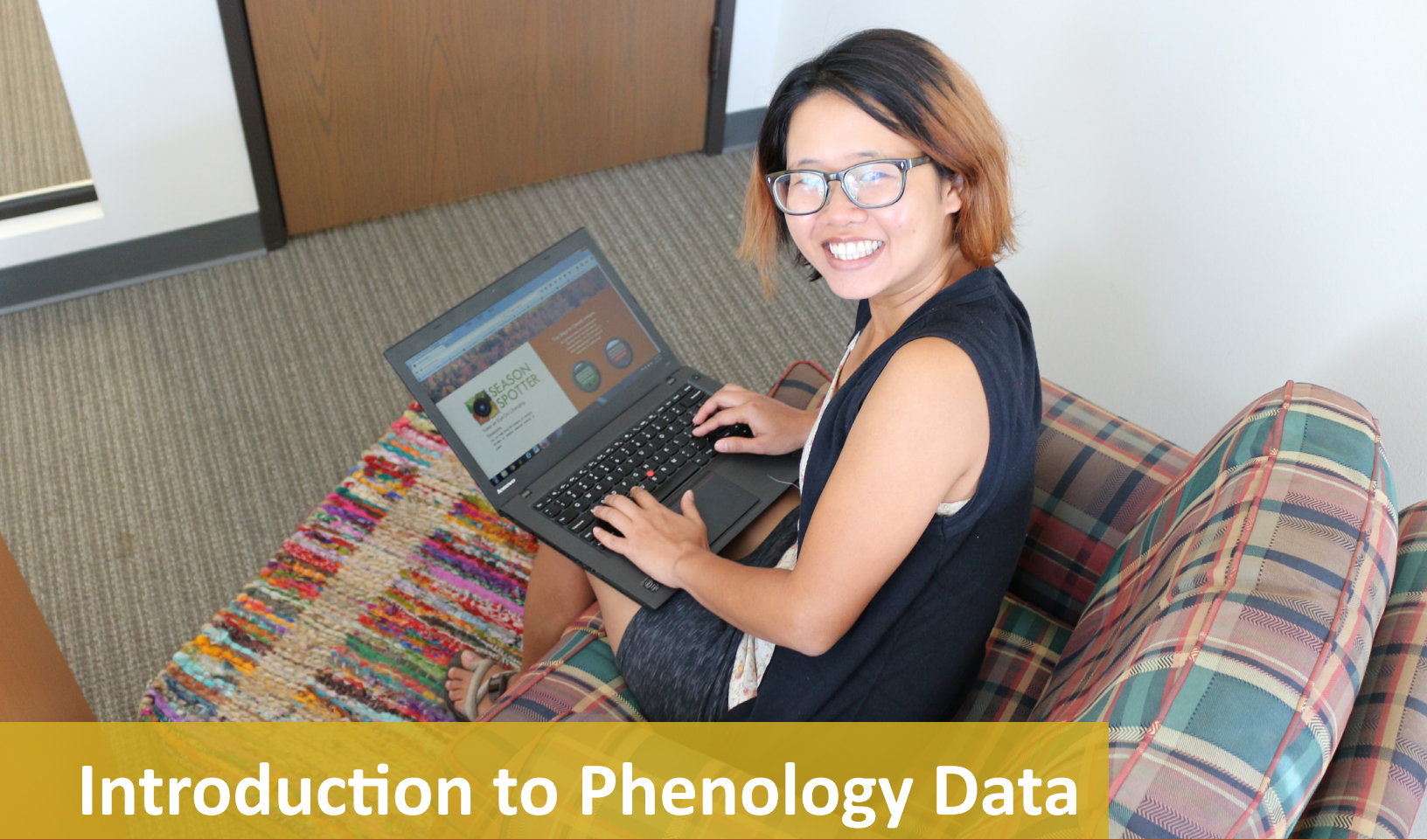


Phenology 101 for Educators

Introduction to Phenology Data





Introduction to Phenology Data

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Welcome to Introduction to Phenology Data

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 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 12



Learning Objectives

- Become familiar with the types of scientific questions that can be asked and answered using PhenoCam images and data.
- Understand how PhenoCam images are turned into data.
- Practice answering scientific questions using phenology data including PhenoCam images and data.
- Understand how PhenoCam data contributes to scientific research and inquiry.

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 how working with PhenoCam data relates to learning standards
- ✓ Learn how the colors in a PhenoCam image can be turned into data
- ✓ Analyze graphs of PhenoCam data



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.

Importance of PhenoCam Data

PhenoCam Data and Learning Standards

Let's get started with a summary of what working with [PhenoCam](#) data can do for students. There are many benefits:

Gaining experience with scientific practices

With the announcement of the new [Framework for K-12 science education standards](#) (NRC 2012) and [Next Generation Science Standards \(NGSS\)](#) (Achieve 2013), educators are increasingly expected to integrate scientific practices with instruction on core ideas and crosscutting themes. The overarching goal of the new framework is to make sure that all students develop an understanding of the nature of science, and the capacity to discuss and think critically about science-related issues – outcomes that existing educational approaches are not achieving. As educational standards from the new framework are adopted, students will be expected to use scientific practices – such as planning and carrying out investigations, and analyzing and interpreting data - to deepen their understanding of core ideas. PhenoCam educational activities engage students directly in scientific practices.

Gaining experience working with data

At the heart of all scientific investigations are data. Another critical element of instruction in science and math involves helping students understand data. Learning how to collect, visualize, summarize, analyze and interpret data are skills central to the NGSS (see NGSS SEP #4 Analyzing and Interpreting Data, Goals by Grade 12 below). Participation in PhenoCam provides students with direct experience observing and recording specific biological events and in so doing generating authentic data. This direct experience collecting data helps students better understand the meaning and limitations of PhenoCam data, both their own and data available from past years. Further, as students are challenged to make meaning of their data (the focus of this course), they develop experience with data analysis and interpretation while also developing an appreciation for data quality issues.

NGSS Scientific and Engineering Practice #4 Analyzing and Interpreting Data Goals by Grade 12

- Analyze data systematically, either to look for salient patterns or to test whether data are consistent with an initial hypothesis.
- Recognize when data are in conflict with expectations and consider what revisions in the initial model are needed.
- Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and information and computer technology to collate, summarize, and display data and to explore relationships between variables, especially those representing input and output.
- Evaluate the strength of a conclusion that can be inferred from any data set, using appropriate grade-level mathematical and statistical techniques.
- Recognize patterns in data that suggest relationships worth investigating further. Distinguish between causal and correlation relationships.

Turning PhenoCam Images into Data

Taking a Closer Look at Color

To understand how PhenoCam scientists turn images into data, it's helpful have some background on how our eyes (and the cameras!) see color.

The colors we see come from difference in how objects absorb and reflect light. Light is *electromagnetic radiation* - a form of energy. It travels in waves - from very long waves to tiny waves the size of an atom. Visible light is light that we can see. This is called white light even though it seems to be colorless. White light is actually a mixture of many different colors - the colors of the rainbow. These are additive colors. It doesn't quite work the same as mixing paint!

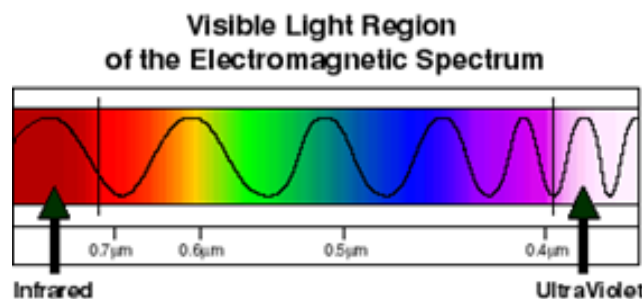


Figure 1 - Visible light region of the electromagnetic spectrum. Credit: NASA.

When different *wavelengths* of light hit our eyes, we see different colors. Light from the sun or light bulbs has many different wavelengths. If the light hits an object - a road, tree, house, anything really - the object absorbs some wavelengths. Other wavelengths are reflected, and those are the ones we see. When an object absorbs all wavelengths to a great extent, it appears black. If it largely reflects all light, it appears white. Objects that absorb only a fraction of all the wavelengths appear colored.

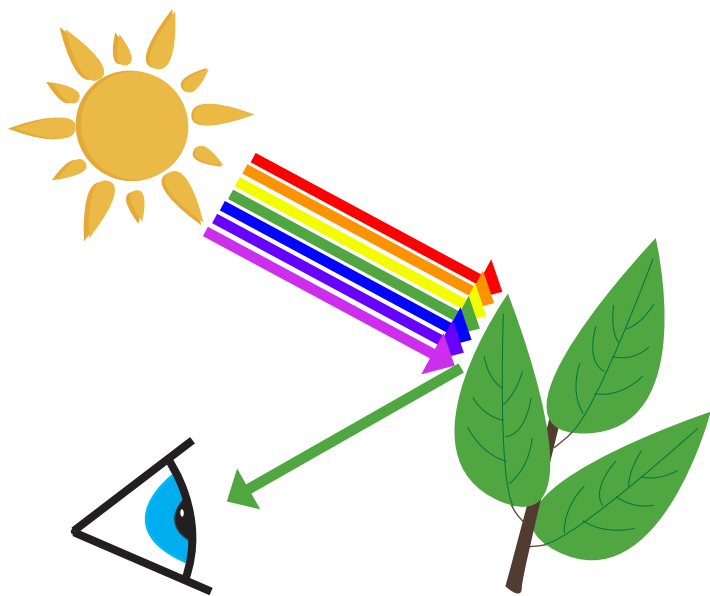


Figure 2 - The chlorophyll pigment in plants absorbs most of the wavelengths from white light and reflects the green wavelength. This is why plants are such a beautiful green color.

Think about it...

Take a look at the PhenoCam image below from Arbutus Lake in New York. What colors are being absorbed and reflected for your eyes to see the trees as green? What colors are being absorbed and reflected for your eyes to register the lake as blue in color?



Turning PhenoCam Images into Data

Turning Color into Data

Different combinations of additive colors - red, green, and blue light - make all the colors we can see. This is how computer monitors generate colors.

The colors on a computer screen all have *red, green, and blue (RGB) values* from 0 to 255. Each color has specific values of red, green, and blue that are combined to make that color. We can use these specific values to quantify the color and thus turn it into data.



Activity 1

What do you see on your monitor?

Explore the different RGB combinations your computer uses to make the colors on your screen. You can use the color meter feature on your computer, to click on different areas of your computer screen and learn how much of each color makes up that pixel. Before clicking on a specific pixel, try to guess the RGB value of that pixel. How would the color of the pixel you tested change if the R value increased? If the G or B value decreased?



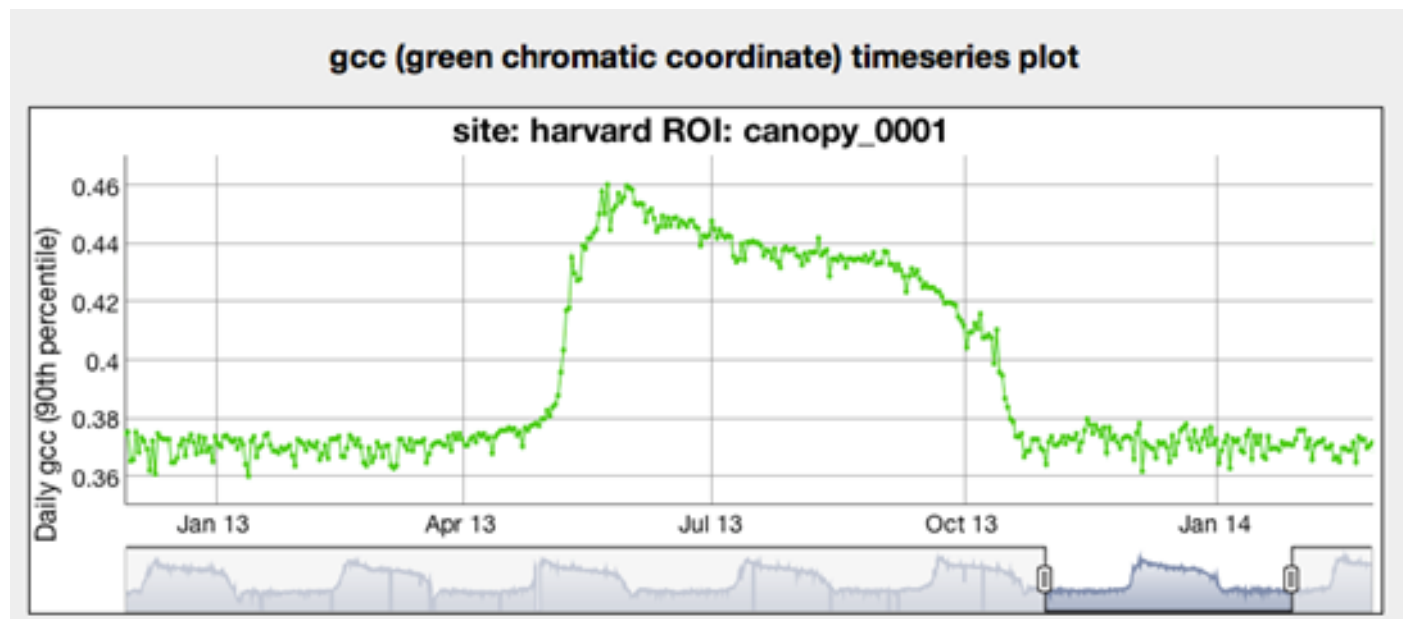
Investigating PhenoCam Data

Analyzing PhenoCam Data

The computer program used in the Phenocam project analyzes the colors in the canopy in each picture. The green level is divided by the levels of red, blue, and green added together. The resulting number is the *Green Chromatic Coordinate* or GCC value.

$$\text{Green Chromatic Coordinate (GCC)} = \frac{\text{Green}}{\text{Red} + \text{Green} + \text{Blue}}$$

This GCC value provides information about the amount of foliage present and its color. Just by looking at the GCC number you can tell when *bud burst* happened and when the leaves turn color in the fall. So what do GCC values look like when graphed? Let's take a look!

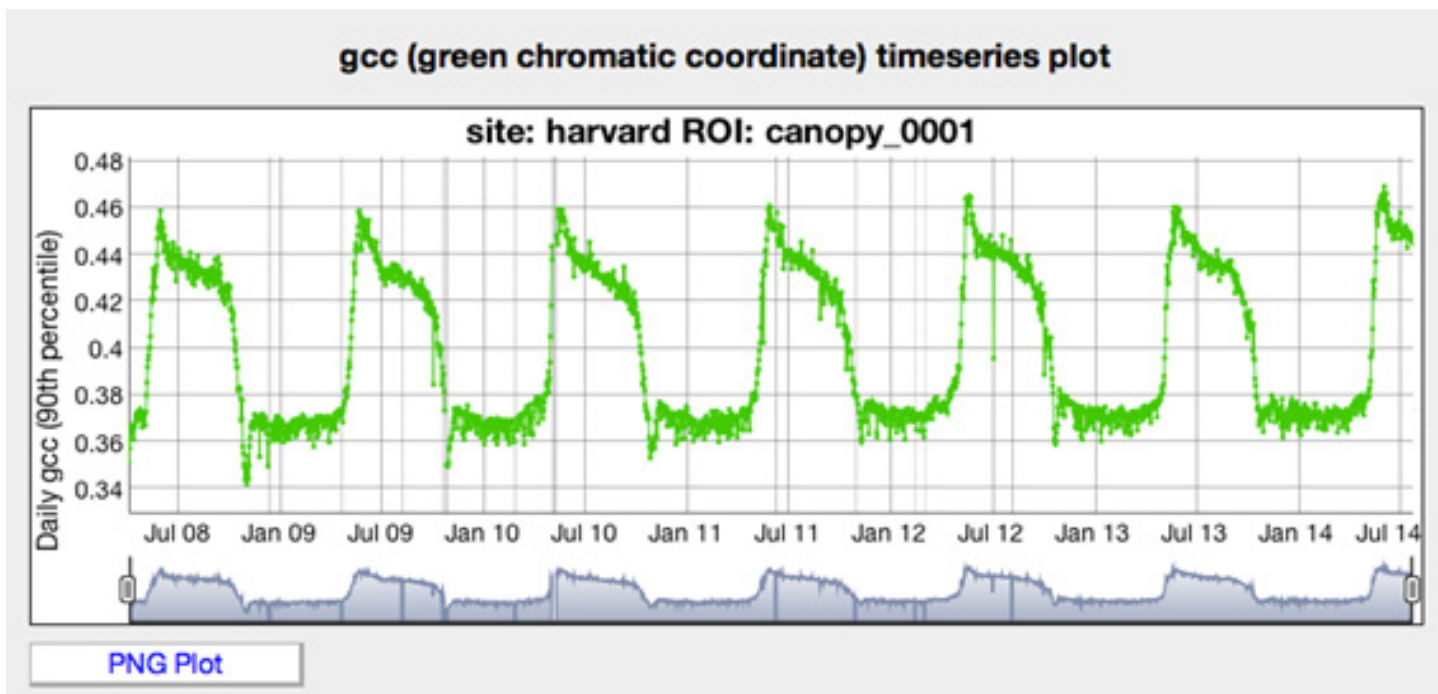


The graph above shows the GCC values from the [Harvard Forest phenocam](#) over one year. As the leaves emerge and start *photosynthesizing*, the *chlorophyll* pigments increase resulting in increased green color. Chlorophyll decreases throughout the summer and dies off during *senescence*. Using GCC values, you can track relative changes in greenness for an entire growing season.

Investigating PhenoCam Data

PhenoCam Data Over Time

On the previous page you looked at one year of data from Harvard Forest; however, the PhenoCam Network is continuously taking photos at each site. What does GCC data look like at one site over multiple years?



This second graph shows GCC values at Harvard Forest over multiple growing seasons. When GCC values for multiple years are combined, you can start to see trends and patterns in the data. Looking at the graph above, are there any trends that stick out to you?

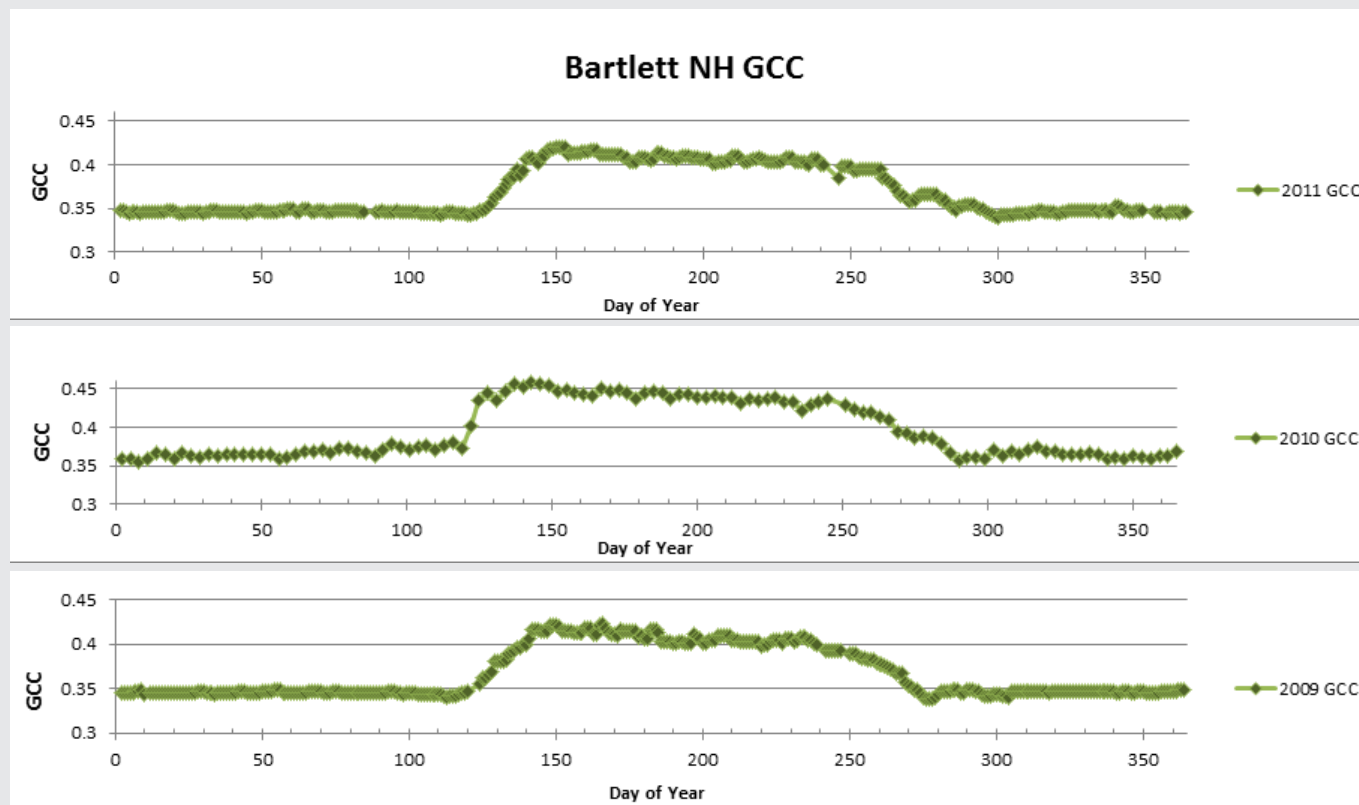
The purpose of the Phenocam network is to collect this kind of data year after year in many different places to look at seasonal patterns and climate change. With more than 80 cameras at different sites uploading half-hourly imagery to the PhenoCam server, there's a lot of data to analyze!

Investigating PhenoCam Data

Activity 2

Analyze PhenoCam Data

The images below show three years of GCC data at the Bartlett PhenoCam site in New Hampshire. The questions below will guide you in analyzing the data.



Q1. Which year had the earliest budburst? Which year had the latest budburst?

Q2. When did the leaves start to lose their color each year? Was the date similar or different between the three years?

Q3. If temperatures were warmer in 2012, what changes might you expect to see in the graph for that year?

This exercise could be used as a part of a lesson or group discussion when introducing PhenoCam data in your classroom or informal educational setting.

1. The Phenocam project used a computer to analyze the colors in the canopy in each picture.
True
False
2. Which of the following are goals by Grade 12 from the NGSS SEP #4 Analyzing and Interpreting Data?
 - a. Analyze data systematically, either to look for salient patterns or to test whether data are consistent with an initial hypothesis.
 - b. Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and information and computer technology to collate, summarize, and display data and to explore relationships between variables, especially those representing input and output.
 - c. Recognize patterns in data that suggest relationships worth investigating further. Distinguish between causal and correlation relationships.
 - d. All of the above
3. When GCC values for multiple years are combined:
 - a. You can draw conclusions about changes in individual plant species.
 - b. You can start to see trends and patterns in the data.
 - c. Computers are needed to further analyze the data.
 - d. Both b and c
4. The Green Chromatic Coordinate or GCC value can be described as:
 - a. The level of green is added together then divided by the red, blue, and green levels.
 - b. A number that can tell you when budburst happened and when the leaves turn color in the fall.
 - c. The average RBG value of a PhenoCam image.
 - d. Both a and b
5. The purpose of the Phenocam network is to collect phenology data year after year in many different places to look at seasonal patterns affected by climate change.
True
False

Answer Key

1. True 2. d 3. b 4. d 5. True

Introduction to PhenoCam Data

Review and Glossary



As you've seen from this guide, national datasets, such as PhenoCam data, are extremely important! These data can be used to effectively answer questions about the influence of climate change or landuse change on the plants, animals and environment around us.

This background guide introduced you to the importance of PhenoCam data, beginning with a discussion of how working with PhenoCam data addresses various scientific practices as identified in educational standards, how the science behind PhenoCam works, and what types of scientific questions PhenoCam data can help us address. These are the types of issues that may be important to present to students when using PhenoCam data in your educational setting!



Next up...

- Explore the supplementary *Introduction to PhenoCam Data* resources (Student activities, videos, etc.).

Links from this Unit

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

Framework for K-12 science education standards: <http://www.nextgenscience.org/framework-k%E2%80%9312-science-education>

Next Generation Science Standards: <http://www.nextgenscience.org/get-to-know>

PhenoCam Network map: <https://phenocam.sr.unh.edu/webcam/network/map/>

PhenoCam data (require account creation):
<https://phenocam.sr.unh.edu/webcam/accounts/login/?next=/webcam/network/download/>

Project BudBurst: <http://budburst.org>

Season Spotter: <http://seasonspotter.org>

Review and Glossary

Glossary

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

Bud Burst: Date when the protective scale coating is shed from the bud exposing tender new growth tissues of one or more flower buds or leaves.

Chlorophyll: Green pigments found in algae and plants.

Electromagnetic radiation: Energy that travels in waves and spans a broad spectrum from very long radio waves to very short gamma rays. The human eye can only detect only a small portion of this spectrum called visible light. A radio detects a different portion of the spectrum, and an x-ray machine uses yet another portion.

Green Chromatic Coordinate (GCC) Value: The green level divided by the levels of red, blue, and green in an image added together. This number can tell you when bud burst happened and when the leaves turn color in the fall.

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.

Photosynthesis: Process by which plants grow by converting sunlight into energy

Red, green, and blue (RGB) values: Date when the first fruits become fully ripe or seeds drop naturally from the plant on 3 or more branches. Ripening is often indicated by a change to the mature color or by drying and splitting open.

Senescence: The final stage of plant development during which the plant reclaims the valuable cellular building blocks that have been deposited in the leaves and other parts of the plant during growth. Maintaining an efficient senescence process is essential for survival of the plant or its future generations.

Wavelength: The distance between one peak or crest of a wave of light, heat, or other energy and the next peak or crest.

PhenoCam for Educators

Monitoring Phenology