Using GLOBE's Plant Phenology to Monitor the Growing Season

by Ruth Bombaugh, Elena Sparrow, and Tarun Mal

Phenology is the study of living organisms' response to seasonal and climatic changes in their environment. Seasonal changes include variations in day length or duration of sunlight, precipitation, temperature, etc. For all land creatures, the "greening-up" of plants in the spring and their "greening-down," or *senescence*, in the fall defines the growing season when plants are making food through photosynthesis. For all land creatures, the photosynthetic activity of plants is what makes survival possible.

Plant phenology, and more specifically the growing season, has always been critically important to humankind. In ancient times the astronomer who could predict the seasons was the king's chief advisor and people worshiped goddesses, such as Ceres and Persephone, who controlled the growing season.

Most modern people no longer worship Earth goddesses, but we still are acutely aware of the growing season and anything that might interfere with it, such as drought, floods, late or early frosts, unusually heavy rains at harvest time, etc. We also are becoming more aware of the role of carbon dioxide as one of the "greenhouse gases" that regulates temperature on our planet. Plants take up carbon dioxide during photosynthesis, so the growing season is critically important for that reason as well.

Why study it?

So what if the growing season in the United Sates and western Canada has increased by eight days since the early 1980s? The number of frost-free days is one of the most important determinants for which plants can grow in a particular location, and also potentially brings other (less welcome) changes in rainfall or average temperatures. Think of the ramifications! This is exactly what some scientists (Myneni et al. 1997) are suggesting based on satellite data. But satellite data can be misleading. Remote sensing estimates from satellites vary because of problems such as interference from small and large clouds, atmospheric haze, low Sun angles at high latitudes, change of Sun angles with seasons, and poor viewing geometry. Even though NASA is coming up with new and better satellite data (from the MODIS, or Moderate Resolution Imaging Spectrometer, on board the Terra satellite launched in 1999), "ground truthing" or data collected by people on the Earth, is required for verification. Healthy green plants reflect much more near-

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infrared sunlight than visible light, thus satellites can detect the growing season by the wave of green that washes over the land surface during spring and then retreats during the fall. As noted above, however, inaccuracies can occur, so ground truthing is needed to help verify satellite-derived findings. The GLOBE (Global Learning and Observations To Benefit the Environment) program is designed to address this need by bringing the research to the classroom.

GLOBE needs no introduction for the more than 10,000 schools that participate as research sites. Its sophisticated website (*www.globe.gov*) welcomes students to not only publish their own environmental data, but also to create visualizations comparing their data to other schools', to chat with other GLOBE classrooms and scientists, and even to report self-initiated research projects. The archive of student data is steadily growing in GLOBE's four core research areas—atmosphere (weather), hydrology (water), land cover/biology, and soil. (See the September 2001 issue of *Science Scope* for a sample atmosphere protocol.) As it continues to grow, the GLOBE data archive is becoming more and more valuable as an independent data source due to the consistency of the protocols and the large distribution of GLOBE schools around the world. Because students are numerous enough and widely distributed enough to provide extensive data, one of GLOBE's most important (potential) implementations is ground truthing satellite data.

Recently, GLOBE added two new protocols, "green-up" and "green-down" to its phenology area of investigation. These protocols are both fun and easy to do, while at the same time critically important. Where there are deciduous forests, students can watch for the bursting of leaf buds in the spring and the color changes and leaf drop in the autumn. Where there are grasslands, students can watch for the new growth of grass in the spring and the dying back of the grass in the fall. Best of all, the phenology protocols are very "doable" because they require a minimal time commitment; you only have to perform them a short time twice a year (spring and fall) and only for a few minutes each day during those twice-yearly data-collection intervals. Let's look at each of these protocols a bit more closely. The following descriptions are summaries. For the full details, check the GLOBE website, *www.globe.gov*.

Plant phenology protocol with deciduous trees or shrubs

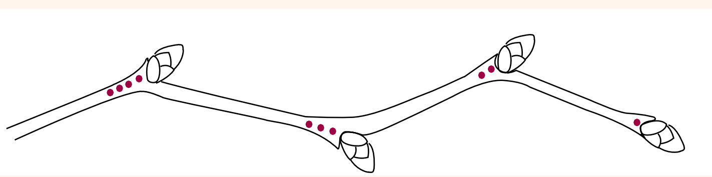
Step 1: Site location

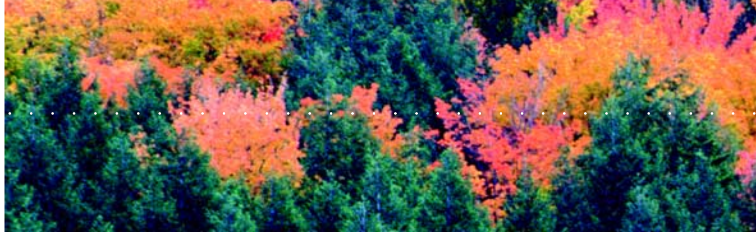
When helping your students select two trees, keep in mind the main purpose; your students are ground truthing satellite data on the growing season for your area. You want trees that are native so that they truly reflect your particular growing season. You also want trees that are not near buildings and that are not watered or fertilized because these factors would also interfere with the greening cycle. Ideally, your trees will have the largest share of canopy in your region because the green-up and green-down detected by satellites would be influenced mostly by these trees. You will want to use one to three over-story species that are dominant in your region. An "over-story" is a tree species that typically is taller than the other trees and therefore stands over them. Also, ideally your trees would be a part of a GLOBE land cover/biology site or a soil site and you would have atmosphere data collected near them. This is only the ideal but not necessary for a very worthwhile project just doing the phenology alone. GLOBE is interested in all data, so simply do the best you can in selecting two trees that your students can visit twice weekly or daily during the week(s) you are collecting phenology data. A group of inner-city schools in Cleveland, Ohio that piloted the green-down protocols, for example, used any native species of tree they could find that was near their school and had a low branch. Fortunately, these trees weren't pampered with water or fertilizer. They were, however, unavoidably close to buildings and students made sure they reported the closeness to buildings in their site description.

Once you and your students have selected the two trees, locate them with a GPS, and take pictures in all four directions. All information and directions are on the GLOBE site. Also, GLOBE teachers can borrow a GPS unit from the GLOBE office or from a local GLOBE partnership. Non-GLOBE teachers could borrow the GPS unit from a local college or city planning office or a local sportsperson. You have now identified your GLOBE phenology site!

Keep in mind that scientists would like at least 10 good solid years of data. The more long-term the data is, the more valuable and interesting it is. However, a 10-year commitment is not required at all. By using the same trees (and if at all possible, the same branches) year-after-year, you automatically eliminate a lot of extraneous variables that could interfere with your results. Different species of trees, for example, vary as to when they start and end their active growing season. One further note is that your selected (large) branch should be on the south side of the tree

FIGURE 1 Marking bud-burst





if you're in the Northern Hemisphere and on the north side of the tree if you live in the Southern Hemisphere. In the northern latitudes, the leaves facing the south will receive the most sunlight, and in the southern latitudes the leaves facing north will receive the most sunlight. You need a lower branch that students can observe readily, but try to find one that is at the edge of a stand since branches inside a stand may experience a different microclimate due to shading.

Step 2: Green-up in the spring

"Bud-burst" refers to the swelling up of the leaf bud in the spring when the bud reveals its first tiny glimpse of the green leaf that is ready to start to emerge. You need to start the "green-up" protocol a few weeks before bud-burst normally occurs. Mark the branch on each of the two trees your students are observing with a flagging tape or some other durable identification and includes a unique number (assigned by the teacher so the tree and branch are easy to find again) plus your name/group name, school name, and class. Locate the bud at the end of the branch and label it (Any indelible marker is fine. Mark on the bark and it will not harm the tree or branch.) by marking one dot on the branch next to the bud. Locate three other buds closest to this bud and label these buds by marking two, three, or four dots next to them (see Figure 1). Now you and your students are ready to observe twice weekly!

On a chart, record each time your students visit the tree (see Figure 2). Record if no swelling has occurred, when it first occurs, and when your students first observe bud-burst. (Remember: bud-burst is when a tiny bit of green is first visible in the swollen bud indicating that the leaf is starting to emerge.) As the leaf emerges, students can use a metric ruler to measure the leaf from its tip to its base. Occasionally the bud or the leaf breaks off, so it is important to be gentle! If it does break off, the students note that on their chart and they are done collecting data on that leaf or bud. Hopefully the other leaves will still give good data until collection is finished.

The measurements should *not* include the leaf stem, or *petiole*. When the leaf stops increasing in length, students are finished measuring and it's time to have fun with the data by graphing the leaf growth and calculating the percent of leaf growth. To graph the leaf growth, put the leaf length on the y-axis and the dates on the x-axis. To calculate the percent leaf growth, divide the length (mm) of each leaf for each observation by the length of the mature leaf (mm) at the end of the observations.

Step 3: Green-down, or senescence

In the fall, you need to start the green-down a few weeks before the leaves normally start to change color. Again, you will need to select a branch on each of the two trees and label your leaves in the same manner as you did with your branches and buds in the bud-burst activity. Use the same branch if possible. Once your four leaves from each of the two trees are selected, your students can begin observing and recording data on a chart similar to the chart in Figure 2. Students will need GLOBE's official color chart to successfully collect this data and publish their findings on the web.

We still are acutely aware of the growing season and anything that might interfere with it.

Plant phenology protocol in a grassland area

Step 1: Site location

Select a one-meter square area dominated by grass plants and mark it with stakes or other durable identifiers. The stakes could be brightly painted to minimize the danger of people walking into them. Try to have the site at least 100 meters away from any building. Identify the genus and species of the grasses using field guides or the help of plant specialists. Finally, take a photograph from the center of your site to the north, south, east, and west directions. You now have your GLOBE phenology site!

Step 2: Green-up

Look for new green grass shoots and mark the base of the first grass shoot with a single dot when you first find it. Mark the second shoot with two dots, the third with three dots and the fourth shoot with four dots. Visit the site twice weekly. Use a metric ruler to measure the length of the shoots in millimeters or centimeters. Keep measuring the grass until the shoot length stops increasing. There is, of course, a risk that the grass may be damaged by an animal or other situation. This case would be analogous

FIGURE 2 **GLOBE phenology data example**

Date	Terminal leaf/Bud	Bud/Leaf 2	Bud/Leaf 3	Bud/Leaf 4
March 31, 2002	Bud dormant	Bud dormant	Bud dormant	Bud dormant
April 2, 2002	Bud dormant	Bud dormant	Bud dormant	Bud dormant
April 7, 2002	Bud dormant	Bud dormant	Bud dormant	Bud dormant
April 10, 2002	Bud slightly swollen	Bud dormant	Bud dormant	Bud dormant
April 14, 2002	Bud still only slightly swollen	Bud slightly swollen	Bud dormant	Bud dormant

to the leaf or bud dropping off the tree during data collection—a note would be made on the chart and data collection would stop. Unfortunately, in real science this sort of thing can happen.

Step 3: Green-down

Return to your grass plot in late autumn. Look for the four longest green grass shoots. Mark the base of the longest grass shoot with a single dot, the second shoot with two dots, the third with three dots and the fourth shoot with four dots. Visit your grass twice weekly and record when it dies back or when it is completely covered with snow.

Conclusion

Teachers handle the management issues for this project in a variety of ways. If a student is allergic to trees or grasses, he or she could still contribute to the class project by doing the data analysis or inputting the data on the web. Most teachers first set up the phenology site with a few students outside of class time and then take the entire class out to the site for the initial data collection. After the initial data collection, the teacher can assign rotating pairs of (trustworthy) students to collect the data. One of our schools has a tree right outside the teacher's window where she can keep an eye on her students. Another school has its science classroom on the second floor and the teacher has chosen a branch that is immediately outside the window. Yet a third school has the tree in the front yard within view of the principal's office. If the school has teacher aids or other adults, that would be helpful also. Other teachers have used the phenology site for science clubs or individual science projects.

In order to participate fully in the program, schools must have scientific measurement instruments that meet GLOBE specifications, as well as a computer with access to the Internet that students are able to use. There is no cost for any educational materials provided by GLOBE or for use of any of GLOBE's resources. However, certification workshops may charge fees and an investment may be required to get scientific measurement instruments up to GLOBE specifications.

This activity ties to the *National Science Education Standards*, Content Standard A: Abilities necessary to do scientific inquiry which enables students to increase their understanding by learning to communicate like scientists, as well as all the standards pertaining to the nature of science or learning how to measure. For example Content Standard A: "As a result of activities in grades 5–8, all students should develop abilities necessary to do scientific inquiry and understandings about scientific inquiry" and Content Standard G: "As a result of activities in grades 5–8, all students should develop understandings of science as a human endeavor, nature of science and history of science" (NRC 1996).

Our hope is two-fold: First, that GLOBE teachers will start to perform the phenology protocols with their students and publish their results on the Internet, and second, that non-GLOBE certified readers will be motivated to find out more about the program and decide to become GLOBE-certified themselves! Dates and places for current GLOBE certification workshops can be found online (see Resources).

Has the growing season in North America increased by eight days? Is it still increasing? Middle-schoolers can help sleuth the answer with GLOBE phenology data collected at many school sites over a long time period. It was the 40 years of data collected on atmospheric concentrations of CO_2 at Mauna Loa Observatory, Hawaii and at the South Pole that alerted scientists to the possibility of a global greenhouse effect (Hughes 2000). Now middle-schoolers can take an active part in the scientific enterprise by monitoring plant phenology locally and contributing to the worldwide GLOBE data bank. ■

Resources

GLOBE website—*www.globe.gov/globe_flash.html*
Phenology protocols—*archive.globe.gov/sda/tg01/phenology.pdf*
The Ecologist magazine—*www.theecologist.org*

References

Hughes, L. 2000. Biological consequences of global warming: Is the signal already. *Trends in Ecology and Evolution* 15, 56–61.
Myneni, R.B., C.D. Keeling, C.J. Tucker, et al. 1997. Increased plant growth in the northern high latitudes from 1981–1997. *Nature* 368, 698-701.
National Research Council (NRC). 1996. *National science education standards*. Washington D.C.: National Academy Press.