Green-Down Protocol

Purpose

To observe plant green-down and report green-down data to help validate estimates of the end of the plant growing season

Overview

Students monitor the change in color of selected leaves of trees, shrubs or grasses.

Student Outcomes

Students will learn to,

- observe when leaves change color at the end of the growing season;
- compare leaf color with colors in the Plant Color Guide;
- identify tree species native to your area;
- examine relationships between green-down and climate factors;
- Predict when the end of the growing season will occur for upcoming seasons;
- compare color changes of different plant species;
- communicate project results with other GLOBE schools;
- collaborate with other GLOBE schools (within your country or other countries); and
- share observations by submitting data to the GLOBE archive.

Science Concepts

Earth and Space Sciences

Weather changes from day to day and over the seasons.

The sun is a major source of energy at the Earth's surface.

Life Sciences

Organisms have basic needs.

Organisms can only survive in environments where their needs are met.

Organisms' functions relate to their environment.

Organisms change the environment in which they live.

Earth has many different environments that support different combinations of organisms.

Plants and animals have life cycles.

Energy for life derives mainly from the Sun.

Living systems require a continuous input of energy to maintain their chemical and physical organizations.

Scientific Inquiry Abilities

Estimating dominant plant species.

Identifying plant species (advanced level).

Observing leaf growth.

Making leaf measurements.

Identify answerable questions.

Design and conduct scientific investigations.

Use appropriate mathematics to analyze data.

Develop descriptions and predictions using evidence.

Recognize and analyze alternative explanations.

Communicate procedures, descriptions, and predictions.

Time

30 minutes excluding travel time

Level

All

Frequency

At least twice a week beginning two weeks prior to the anticipated start of green-down, continuing until plant color change has ended or leaves have dropped off

Materials and Tools

Grass Green-Down Field Guide and/or *Tree and Shrub Green-Down Field Guide*
Tree and Shrub Green-Up and Green-Down Site Selection Field Guide and/or *Grass Green-Up and Green-Down Site Selection Field Guide*
Tree, Shrub, and Grass Green-Down Data Sheet
Green-Up and Green-Down Site Definition Sheet
Flagging tape, 1 label per student
Compass
Camera
Pencils
GLOBE Plant Color Guide
Green-Down Data Sheet
Fine-tip permanent marker

Preparation

Review dominant plant species of school's GLOBE Study Site.

Prerequisites

Estimating Cloud Cover: A Simulation (from *Atmosphere Investigation*) (suggested)

Green-Up and Green-Down Site Selection

Before selecting your Green-down site, here are some things to consider. Green-up site selection has the same considerations.

1. Your plant phenology site should be in an area where green-up and green-down of native plants is due to climatic factors such as increased temperature or precipitation. Watering and fertilization alter plants' green-up and green-down cycles, and the data would not be representative of natural vegetation and local climate connections. Buildings absorb solar radiation and shelter sites from wind. Therefore, avoid sites near buildings or where watering or fertilization is done. For the phenology protocols, near means that the plant is closer to a building than the height of the building. To determine if the plant is too close to a building, stand at the plant and sight the top of the building through your clinometer. If the angle is greater than 45°, the building is too close.
2. Non-native species, called exotics, have green-up and green-down cycles that may not be tied to the local climate. Often this is because exotics have not evolved to survive in the local climate. If you are unsure which plants are natives or have evolved to grow in a climate regime similar to yours, ask a local greenhouse or agricultural extension agent, or the appropriate staff at a local college or university.
3. Your green-up and green-down site must be accessible so that students can visit the site at least twice a week. It may be the same as a Land Cover Sample Site or your Atmosphere Study Site. Be sure to determine the location of your site by identifying the latitude, longitude and elevation following the *GPS Protocol*.
4. Because the results of your green-up and green-down measurements may be related to temperature and precipitation data from the *Atmosphere Investigation* and soil moisture and temperature data from the *Soil Investigation*, it is better to choose a site close to the Atmosphere and Soil Moisture Study Sites. The local topography can cause weather to vary even within short distances. This is particularly true in mountainous and coastal regions. The horizontal distance between the Phenology and Atmosphere and Soil Moisture Sites should be less than 2 kilometers and the elevation differences less than 100 meters, so that you can see whether your atmosphere data correlates with your green-up and green-down data.
5. Green-up and green-down detected by satellites are influenced mostly by a few dominant overstory plant species. These will be the species with the largest share of canopy coverage. If you are using a Land Cover Sample Site, you already know the dominant species. If you are using a different site, use the one to three over-story species that are dominant for your region. These over-story plants may be coniferous trees, broadleaf trees, broadleaf shrubs, or grasses. For phenology measurements you should choose a deciduous plant so, if the dominant plant species are all evergreen conifers, use the under-story broadleaf shrubs as your green-up plants. For example, if your study site is 90 percent white pine (a coniferous tree) and 10 percent sugar maple (a broad leaf tree), use the sugar maple trees as the study plants.
6. Scientifically, it is most useful if the tree or shrub branch used for the *Green-Up Protocol* is the same as the one used for the *Green-Down Protocol*. However, you may do only the green-up or green-down measurements or you may use different branches or even different sites if this is necessary to match your educational requirements. If you use different sites for green-up and green-down, create a site definition for each.
7. Since a change in plant growing season may be due to a change in climate, students at your school should try to use the same site, the same plant species, and the same part of the plant consistently, year after year.

Tree and Shrub Green-Up and Green-Down Site Selection
Field Guide

Task

Define the site for green-up and green-down measurement of trees and shrubs.

What You Need

- ❑ *Green-Up and Green-Down Site Definition Sheet*
- ❑ *GPS Data Sheet*
- ❑ *GPS Protocol Field Guide*
- ❑ Flagging tape or other durable identification
- ❑ Dichotomous keys and/or other local species guides
- ❑ GPS receiver
- ❑ Compass
- ❑ Pencil or pen

In the Field

1. Complete the top of the *Green-Up and Green-Down Site Definition Sheet*.

2. Select one tree or shrub. The tree or shrub should be among the dominant native species in your area, deciduous, and easily accessible.

3. Select a healthy and relatively large branch on the south side of the plant in the Northern Hemisphere or the north side of the plant in the Southern Hemisphere. Use a compass or GPS receiver to determine direction. If a lower branch is chosen, it should be on the edge of the stand of trees or shrubs since branches inside a stand may experience a different microclimate due to shading.

4. Identify genus and species using field guides or the help of plant specialists. Record the genus and species on the *Green-Up and Green-Down Site Definition Sheet*.

5. Mark the branch with flagging tape or some other durable identification. Label the flagging tape with a unique number and your name/group name, school name and class.

6. Take a GPS measurement following the *GPS Protocol*.

Grass Green-Up and Green-Down Site Selection
Field Guide

Task

Define the site for green-up and green-down measurement of grasses.

What You Need

- ❑ *Green-Up and Green-Down Site Definition Sheet*
- ❑ *GPS Data Sheet*
- ❑ *GPS Protocol Field Guide*
- ❑ GPS receiver
- ❑ Pencil or pen
- ❑ Nails or stakes or other durable identifiers
- ❑ Meter stick or tape measure
- ❑ Dichotomous keys and/or other local species guides

In the Field

1. Complete the top of the *Green-Up and Green-Down Site Definition Sheet*.

2. Identify genus using field guides or help of plant specialists. Record the genus on the *Green-Up and Green-Down Site Definition Sheet*.

3. Select a one-meter square area dominated by grass plants. Mark your one-meter square plot with nails or stakes or other durable identifiers.

4. Take a GPS measurement following the *GPS Protocol*.

Teacher Support

Advance Preparation

Students should complete the *Estimating Cloud Cover: A Simulation Learning Activity* in the *Atmosphere Investigation* prior to observing green-down. Students will estimate percentage of leaf colors in the green-down observations.

Students should start their observations at least two weeks before expected green-down.

Frequency of Observations

For most areas of the world, there is only one green-up and green-down cycle. However, there are places where multiple wet and dry seasons can occur in a single year, resulting in multiple green-up and green-down cycles. Because of this possibility, we are asking you to report which cycle you are observing. If there is only one cycle, then you report green-down cycle 1. The onset of the first green-down after 1 January is considered green-down cycle 1.

Measurement Procedure

If lower branches are observed, try to sample them from the edge of the stand of trees or shrubs since branches inside a stand may experience a different microclimate due to shading.

In some locations, the end of leaf color change will mark the end of the reporting period.

For each observation, students record the color of the leaf using the GLOBE Plant Color Guide, or if the leaf has fallen or been snow covered. If a leaf has fallen, then no more observations can be made for that leaf. Depending on the snow event, reporting may end as well. The following page shows an example of a completed *Data Sheet.*

Questions for Further Investigation

What other animals (butterflies, waterfowl, songbirds) migrate after plants green-down? When? Why?

Does the timing of green-down occur earlier or later at higher elevations in your region? Why?

Does the timing of green-down occur earlier or later inland or near the coast in your region? Why?

How do fallen plant leaves affect soil properties such as soil color, water-holding capacity, and soil nutrients? How could you find out? Why is this important?

Example of Completed Green-Down Data Sheet

Tree, Shrub, and Grass Green-Down

Date (day and month)	**Leaf 1** (Color, fallen snow covered)	**Leaf 2** (Color, fallen snow covered)	**Leaf 3** (Color, fallen snow covered)	**Leaf 4** (Color, fallen snow covered)	**Reported to GLOBE**
30 September	*5 G 7/4*	*5 G 7/4*	*5 G 7/4*	*5 G 7/4*	☑
3 October	*5 G 7/4*	*5 G 7/4*	*5 G 7/4*	*2.5 Y 8/6*	☑
7 October	*5 G 7/4*	*2.5 Y 8/6*	*5 G 7/4*	*2.5 Y 8/6*	☑
11 October	*5 G 7/4*	*2.5 Y 8/6*	*2.5 Y 8/6*	*2.5 Y 8/6*	☑
14 October	*5 G 7/4*	*2.5 Y 8/6*	*2.5 Y 8/6*	*2.5 Y 8/6*	☑
16 October	*2.5 Y 8/6*	*2.5 Y 8/6*	*2.5 Y 8/6*	*2.5 Y 8/6*	☑
20 October	*2.5 Y 8/6*	*2.5 Y 8/6*	*2.5 Y 8/6*	*7.5 YR 6/4*	❑
23 October	*2.5 Y 8/6*	*2.5 Y 8/6*	*2.5 Y 8/6*	*7.5 YR 6/4*	❑
27 October	*2.5 Y 8/6*	*2.5 Y 8/6*	*2.5 Y 8/6*	*7.5 YR 6/4*	❑
30 October	*2.5 Y 8/6*	*2.5 Y 8/6*	*7.5 YR 6/4*	*7.5 YR 6/4*	❑
4 November	*2.5 Y 8/6*	*7.5 YR 6/4*	*7.5 YR 6/4*	*fallen*	❑
6 November	*2.5 Y 8/6*	*7.5 YR 6/4*	*7.5 YR 6/4*		❑
11 November	*7.5 YR 6/4*	*7.5 YR 6/4*	*7.5 YR 6/4*		❑
14 November	*7.5 YR 6/4*	*7.5 YR 6/4*	*7.5 YR 6/4*		❑
17 November	*7.5 YR 6/4*	*fallen*	*7.5 YR 6/4*		❑
22 November	*7.5 YR 6/4*		*fallen*		❑
29 November	*7.5 YR 6/4*				❑
2 December	*snow covered*				❑
					❑

Tree and Shrub Green-Down Protocol

Field Guide

Task

Observe and record green-down in trees or shrubs.

What You Need

First visit only

- ❑ *Tree, Shrub, and Grass Green-Down Data Sheet*
- ❑ Pencil or pen
- ❑ Camera
- ❑ Compass
- ❑ Fine-Tip Permanent Marker
- ❑ GLOBE Plant Color Guide

Every visit

- ❑ GLOBE Plant Color Guide
- ❑ Pencil or pen
- ❑ *Tree, Shrub, and Grass Green-Down Data Sheet*

In the Field

First visit only/getting started

1. Complete the upper portion of your *Data Sheet*.
2. Locate the leaf at the end of the branch. Label this leaf by marking one dot on the branch next to the leaf stem or petiole. Locate the three other leaves on this branch closest to this terminal leaf.
3. Label these leaves by marking two, three, or four dots next to their stems on the branch.
4. Take a photograph looking in the north, south, east, and west directions.

Every visit

1. Examine each of your four leaves. For each leaf, use the GLOBE Plant Color Guide to estimate the dominant color of each leaf. For example, if leaf 1 appears colored at 60 percent 5G 7/12 and 40 percent 2.5 Y8/10, record the leaf color as 5G 7/12 for that observation date.
2. Record your observations on the *Tree, Shrub, and Grass Green-Down Data Sheet.*
   - If leaf is snow covered, report "snow covered",
   - If leaf has fallen, report "fallen" and stop reporting after that,
   - Otherwise, continue to report the color until the color stops changing.

Grass Green-Down Protocol
Field Guide

Task

Observe and record green-down in grasses.

What You Need

- ❑ *Tree, Shrub, and Grass Green-Down Data Sheet*
- ❑ Pencil or pen
- ❑ Camera
- ❑ Compass
- ❑ Fine-Tip Permanent Marker
- ❑ GLOBE Plant Color Guide

Every visit

- ❑ GLOBE Plant Color Guide
- ❑ Pencil or pen
- ❑ *Tree, Shrub, and Grass Green-Down Data Sheet*

In the Field

First visit only/getting started

1. Fill in the top of your *Data Sheet*.
2. Look for the four longest green grass shoots.
3. Mark the base of the longest grass shoot with a single dot. Mark the second longest shoot with two dots, the third with three dots and the fourth shoot with four dots.
4. Take a photograph looking in the north, south, east, and west directions.

Every visit

1. Examine each of your four grass shoots. For each shoot, use the GLOBE Plant Color Guide to estimate the dominant color percentage of each shoot. For example, if shoot #1 appears colored at 60 percent 5G 7/12 and 40 percent 2.5 Y8/10, record the shoot color as 5G 7/12 for that observation date.
2. Record your observations for each shoot on the *Tree, Shrub, and Grass Green-Down Data Sheet.*
   - If leaf is snow covered, report "snow covered",
   - If leaf has fallen, report "fallen" and stop reporting after that,
   - Otherwise, continue to report the color until the color stops changing.

Frequently Asked Questions

1. Should I use the same leaves I used for green-up?

If possible, use the same branches or grass plot. If you use other plants try to select plants of the same species. If the plants you use for green-down are at a different location than the ones you used for green-up, then define a new site.

Plant Phenology: Green-Down – Looking At Your Data

Are the data reasonable?

The first step in looking at plant phenology data is to see if the data seem reasonable and make sense. You should stop reporting for your selected leaves after the leaves fall off the trees or shrubs or when the leaves have stopped changing color. Figure EA-GD-1. shows the green-down data for Escuela de Ensenanza Media 7 Nicolas Copernico in Buenos Aires, Argentina. See how the leaves change color as the green-down season continues. The data collection ends after the leaves fall off. (Also notice the green-up data – it shows how fast the leaves grow, however, it would be good to know when budburst occurred and when leaf growth stopped.)

Table EA-GD-1 shows a table of green-down data for another school.

Date	Leaf number	Leaf State	Color
20021021	1	F	
20021021	2	F	
20021021	3	F	
20021021	4	C	2.5Y:8/12
20021024	1	C	5GY:4/8
20021024	2	C	5GY:5/10
20021024	3	C	5GY:7/12
20021024	4	C	5GY:4/10

For leaves 1, 2 and 3, color is reported after the leaves fell off the tree. This may be an error in the data. Perhaps the dates were recorded incorrectly and what is reported for October 24 was meant to be for October 21. One way to find out is to contact the school and ask the teacher and students.

Also, notice for leaf 4, there are two observations of color. It was yellow on October 21 (2.5Y:8/12) and then was green again on the 24th (5GY:4/8). Were the dates reported incorrect as may have been the case for leaves 1,2,3?Did the leaf continue to change color? If so, how did it change color and for how long? Did it fall off the tree? From the data reported we cannot know.

What do scientists look for in the data?

Scientists are very interested in when leaves appear in spring and how quickly they expand. The timing and rate of fall leaf changes, such as color changes and leaf drop, are also important. It may seem strange that such easy to observe and common events are important for Earth System Science, but they are. These plant phenological events are directly related to global carbon fixation and the amount of carbon dioxide in the atmosphere. Also they affect and are affected by air temperature and humidity and soil moisture.

For example, many scientists use data from a NASA sensor, the Moderate Resolution Imaging Spectrometer (MODIS), to monitor the seasonal dynamics of vegetation. Green-up/green-down data gathered by GLOBE students, using consistent methods all over the world, are one of the best tools with which to verify the accuracy of these satellite products.

Computer models are one of the main research tools used by scientists to predict the future climate of the planet. Seasonal vegetation patterns and activity is an important component of this research. Many models contain programs that are used to predict the expansion of plant leaf material. Without data against which to compare these models, we cannot believe the model predictions. By using GLOBE green-up/green-down data to help develop these models, scientists will be able to better predict our future climate.

Some applications of GLOBE data can be very specific, in particular when plant phenology is linked to other events. Many plant pests like gypsy moths appear during certain leaf developmental stages. By linking GLOBE green-up data with the appearance of gypsy moths, scientists are working to develop better pest treatment approaches.

In short, by participating in the GLOBE *Green-Up and Green-Down Protocols,* you will be helping to gather data that scientists will use in many fields of Earth System Science, sometimes in unpredictable ways!

An Example of Student Research

A teacher asked the students why do leaves change color in the fall? The students looked at each other and weren't sure why. One student commented that he never thought about it and said that he just took it for granted - leaves turn color in the fall and eventually fall off the trees. After discussing reasons why leaves turn color and eventually fall off in preparation for the dormant vegetation stage during the winter season, the teacher asked if all leaves on all trees turn the same color. The students didn't think so because some trees are red, others are orange, and others are brown or yellow. As a homework assignment, the teacher asked her students to look at green-down data on the GLOBE Web site and make some observations about how leaves turn color in the fall.

The students were somewhat familiar with the GLOBE maps and graphs and realized that sites are defined for all the data students collect. So, they wanted to see if there were any nifty maps or graphs for phenology sites. After clicking on *Maps and Graphs* on the navigation bar, they clicked on *GLOBE Sites* and then, *Green-up/Green-down Site Visualization.* The new page listed phenology sites organized by country. They scrolled through the list of countries and schools and decided to look at green-down data at Suomussalmen Lukio school in Finland. At Suomussalmen Lukio there are 10 phenology sites. They found after looking at graphs of the data for each phenology site that students at Suomussalmen Lukio are collecting phenology data for different species —*Alnus incana*, *Larix deciduas, Betula pubescens*, *Populus tremula*, *Calamagrostis*, and *Betula pendula.* They decided to look more closely at three species at three sites shown in Figures EA-GD-2, EA-GD-3 and EA-GD-4: Figure EA-GD-2 (site GRN-01) with *Alnus incana*, Figure EA-GD-3 (site GRN-02) with *Betula pendula*, Figure EA-GD-4 (site GRN-03) with *Larix decidua*. They also examined the data table that is given in the GLOBE Web site after each graph.

The students made numerous observations.

1. The initial green colors at the start of green-down observations were the same for *Alnus incana* and *Betula pendula* but were different for *Larix deciduas*. They looked at the table of data at the bottom of the graphs for each site and saw that the first two species started with a color of 5GY:4/8 and *L. deciduas* started with 5GY:7/12.
2. The leaf color for *A. incana* did not change much and remained a dark green until the leaves were lost or fallen.
3. The leaf color for *B. pendula* went from dark green to light green, then yellow. Two of the four leaves turned brown before lost or fallen, whereas the other two were more yellow.
4. *L. deciduas* went from a light green to yellow and then orange for three of the leaves. The fourth leaf remained a yellow color.
5. The leaves were lost or had fallen off the different trees on different days. The leaves for *A. incana* fell off around October 3; those for *B. pendula* around September 28 and *L. deciduas* around October 27.

The students concluded that different trees showed different color patterns during the fall. They completed their homework assignment to make some observations on how leaves change color in the fall, but instead of wanting to move on to another topic in class, the students had many more questions!

One student commented that they were only looking at data collected for one year. Will green-down start and end at the same time next year? Another student asked if each tree species showed the same color changes each year. What happens when there is an unusually dry or cold fall? A third student wanted to know if the same color changes will be found for these species at different locations in Finland as well as other countries.

To answer some of their questions, they decided to contact someone in their community who knows about the local vegetation to find out more about the tree species growing around them. As well,

they would do a search for other GLOBE schools to see if they can find green-down data for these species. Then they would compare the color changes of the same species at different locations. They predicted that the same species would change colors in the same way at different locations. They decided to do an experiment: they would select native trees in their area and see if students in another area have been collecting green-down data for the same species. They will observe green-down during the next fall. They predict that the colors of the leaves during green-down for the tree species they select will be very similar to the colors observed by other students in a different area for the same tree species.

Figure EA-GD-1

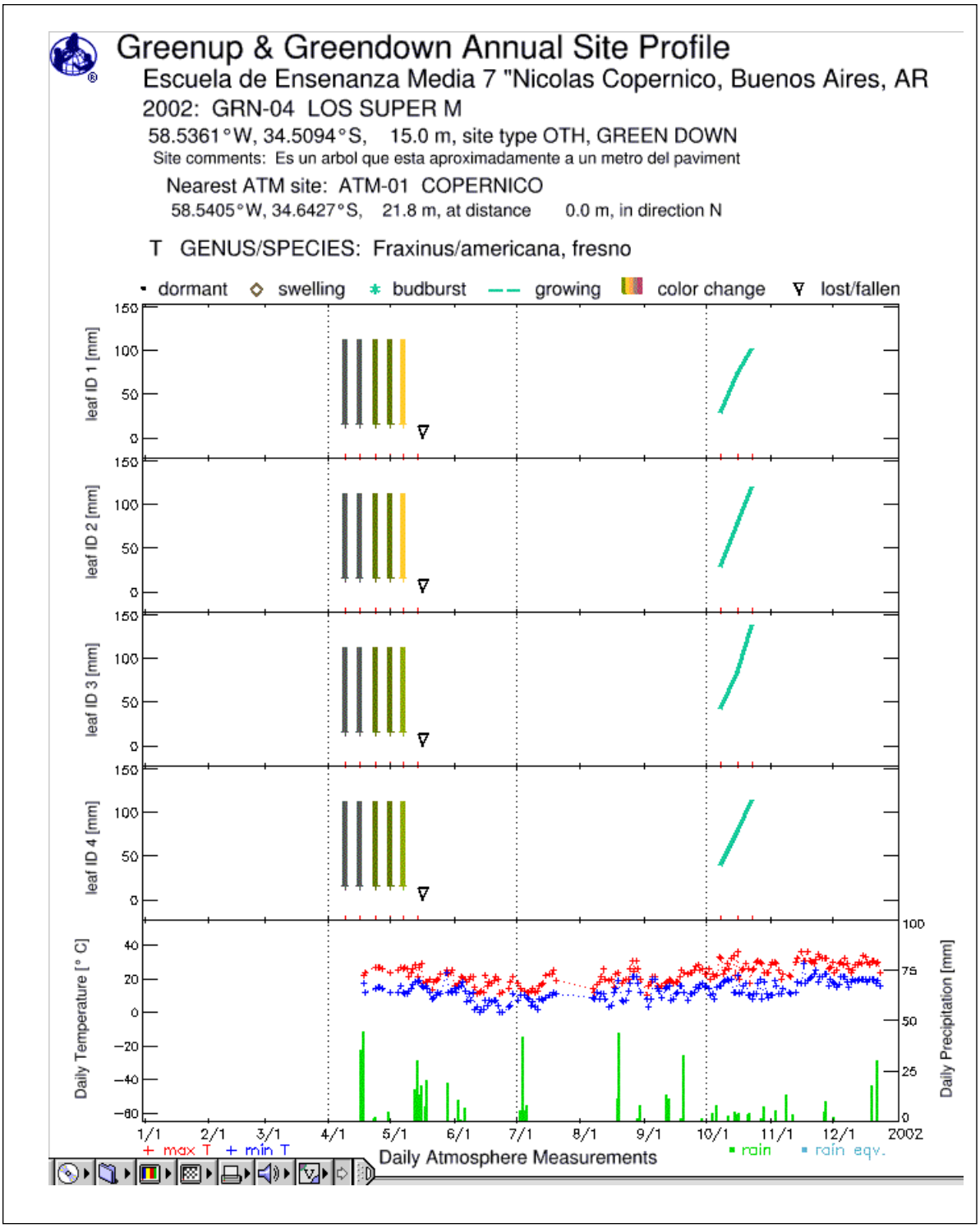

Figure EA-GD-2

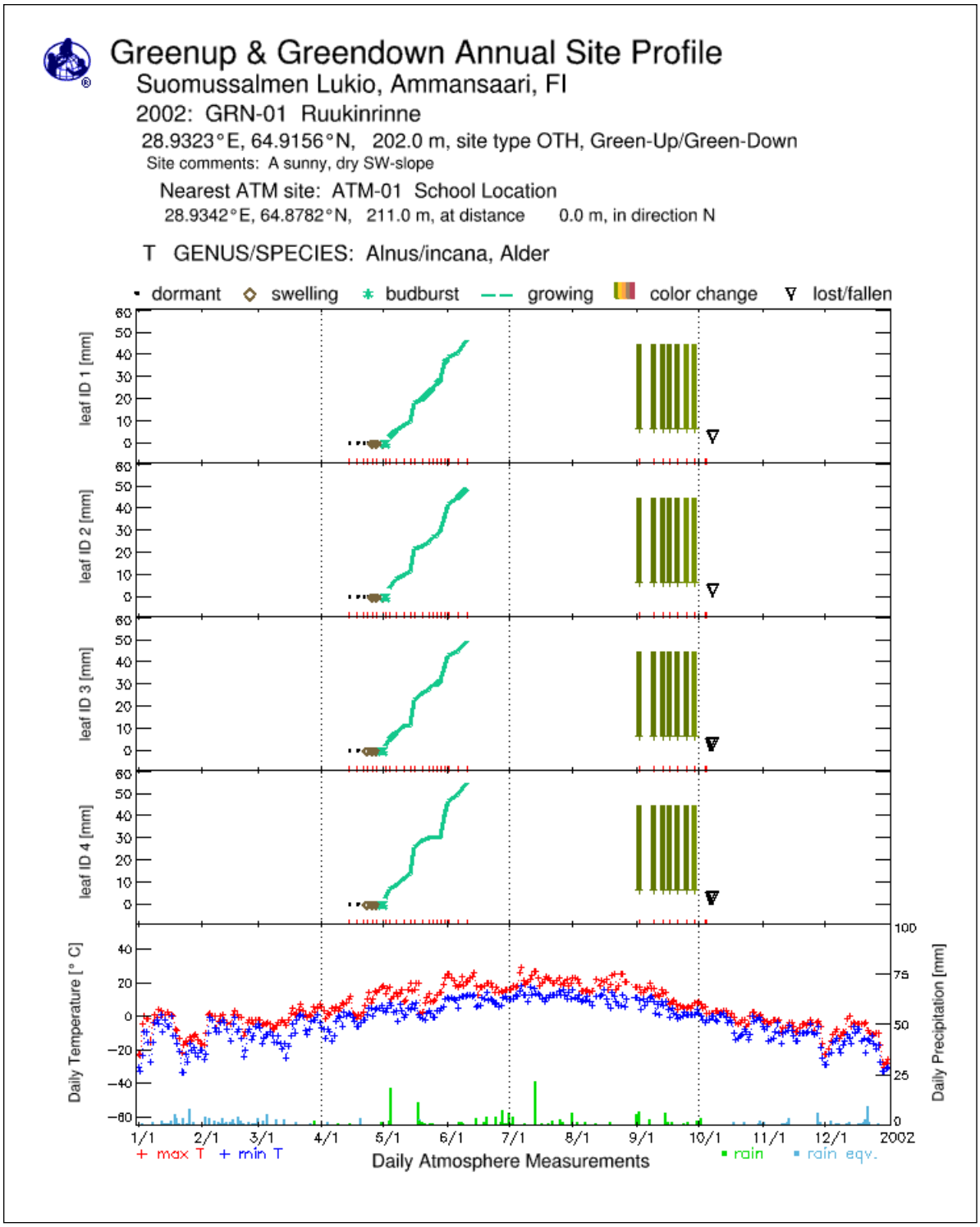

Figure EA-GD-3

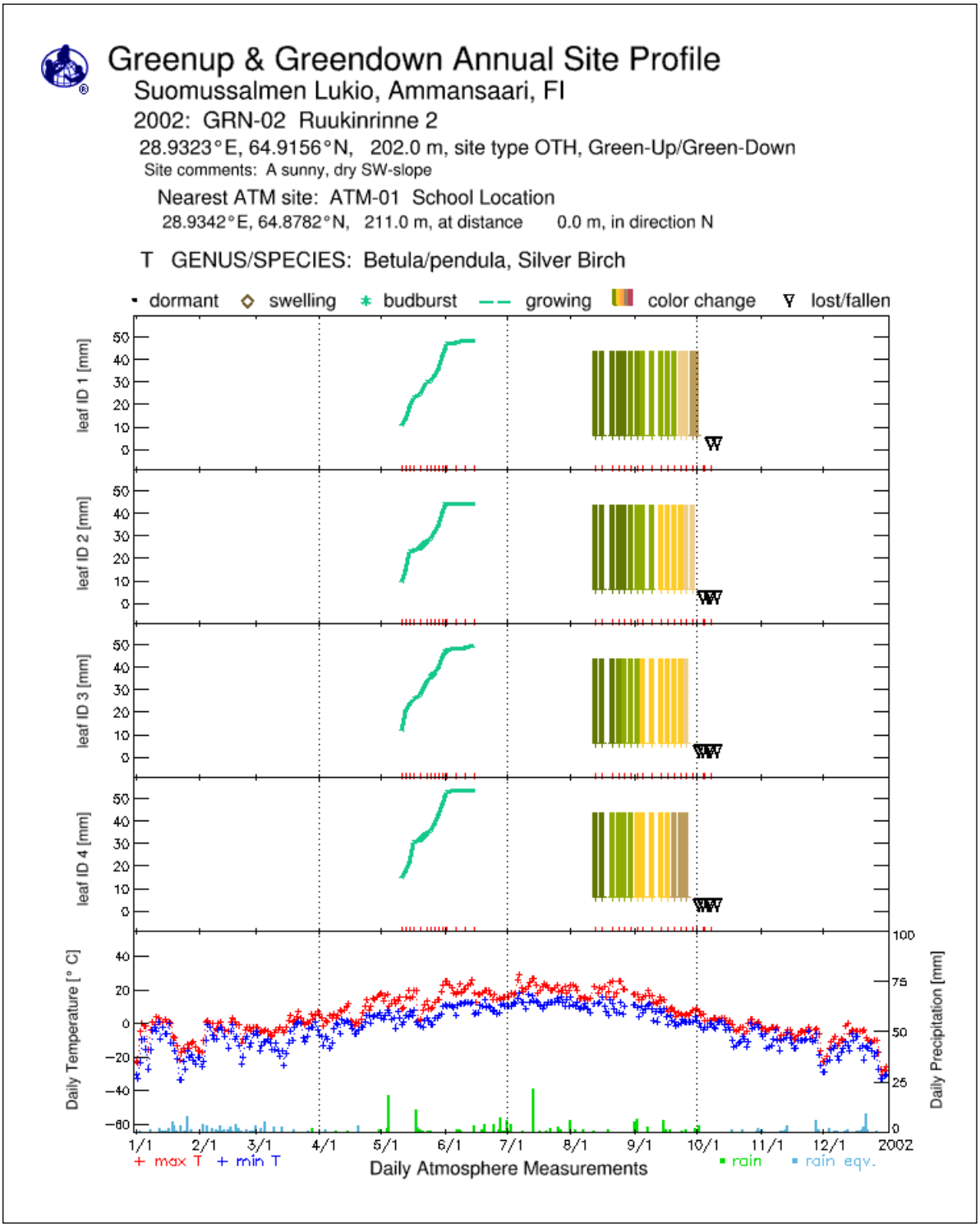

Figure EA-GD-4