# Introduction

## *Summary of Learning Activities*

In *Seasons and Phenology,* students investigate the causes of seasons and their impact on the Earth system, and they explore the effect of environmental changes on plants. During these explorations, students practice basic science process skills such as quantitative and qualitative observation, inference, measurement, prediction, classification, data collection, analysis, and interpretation, and designing and carrying out an investigation. The concepts presented in *Seasons and Phenology* are reinforced through the use of visualization techniques that are important tools for four of the learning activities.

### *Seasons*

There are six learning activities that focus on developing student understanding of seasons. In *What Can We Learn About Our Seasons?* students develop a qualitative understanding of the characteristics and patterns of seasons and highlight the relationship of seasons to physical, biological, and cultural markers. In *What Are Some Factors That Affect Seasonal Patterns?,* students use GLOBE data and graphing tools to compare the influence of latitude, elevation, and geography on seasonal patterns. In *How Do Seasonal Temperature Patterns Vary Among Different Regions of the World?,* students use GLOBE visualizations to display student data on maps and to learn about seasonal changes in regional and global temperature patterns. The activity *What Can We Learn by Sharing Local Seasonal Markers with Other Schools Around the World?* promotes collaboration among teachers during and after the GLOBE teacher training program. It also helps teachers and students learn how the protocols are interconnected and can support inquiry-based investigations.

The last two seasons learning activities use visualizations to enhance student understanding. One of the most important causes of seasonal changes across the globe is the orientation and orbit of Earth in relation to the sun. The spatial model that scientists have designed to explain their observations involves Earth's tilt and the way sunlight spreads across a sphere. Understanding how Earth's relationship to the sun gives us seasons requires an understanding of complex spatial relationships that change over time. In *Modeling the Reasons for Seasonal Change*, students explore these relationships with a 3-D model of Earth that they construct from paper. Aided by depictions of Earth's placement at the equinox and solstice seasonal events, and by simple modeling tools that represent the sun and sunlight as it spreads over a spherical surface, students are guided to an understanding of how the astronomical relationship affects the temperatures and length of day experienced by plants and animals. A color visualization of incoming solar energy offers another source of visual data; in this activity, multiple representations are used to promote coherent student understanding.

As various activities demonstrate, the physical relationship between Earth and the sun is not the only factor that affects seasonal change. In *Seasonal Change on Land and Water*, students use color visualizations and graphs to understand how, at a global level, the presence of large bodies of water (in Earth's Southern Hemisphere) or large land masses (in Earth's Northern Hemisphere) affects the seasons in those regions. By analyzing color visualizations of incoming solar energy and surface temperature, students see that temperature ranges are not entirely consistent with the seasonal pattern of incoming solar energy in the two hemispheres, a result of the difference in heat capacity of large bodies of water and large land masses. Through this activity, students can connect their own local experience of heat capacity and thermal inertia with seasonal differences at a global scale.

### *Phenology*

The phenology learning activities can help students connect global seasonal patterns to global changes in vegetation. There are seven learning activities that focus on developing student understanding of phenology. In *Green-Up Cards,* students participate in an activity, preparatory to doing the phenology protocols, which will help them identify green-up progression in their local plants. This activity also introduces the idea of spatial scale related to plants. In *A Sneak Preview of Budburst,* students

learn what to look for during budburst by observing variations in timing and appearance of leaves of different local plant species. In *A First Look at Phenology,* students observe and classify local plants based on patterns of change other than growth. In *A Beginning Look at Photosynthesis* students learn about plant response to light by setting up simple investigations in the classroom. In *Investigating Leaf Pigments,* students learn about plant pigmentation and photosynthesis while conducting simple investigations that demonstrate the presence of pigments other than chlorophyll in leaves.

The last two phenology learning activities support student analysis through the use of visualizations. While students experience seasonal change mainly in the form of weather and daylight changes (more or less rain, different temperatures, longer or shorter days) and react to these changes by adapting their dress, vegetation undergoes more dramatic and predictable changes that can be studied at a global level using remote sensing. In *Global Patterns in Green-Up and Green-Down*, students investigate the annual cycle of plant growth and decline using color visualizations and graphs. They analyze data on the annual cycle of plant growth/decline and temperature. They find patterns of annual change for the globe and for each hemisphere. Students further explore these patterns in several regions that have different land cover.

After examining the relationship, at a regional level, between seasonal change and green-up/green-down, students can do the *Limiting Factors in Ecosystems* learning activity to understand that physical ecological factors—temperature and precipitation—limit the growth of vegetative ecosystems. Using graphs and color visualizations that show averages of vegetation vigor, temperature, and rainfall for different regions, students look for correlations across data to find potential limiting factors in vegetation growth.

## *Organization of Learning Activities*

The learning activities are organized into two parts based on the focus of the activity: seasons or phenology. See pages 2-3 for a list and brief description of these activities.

# Implementation Considerations

## *Sequence*

In order for students to fully understand the reasons for the patterns of change they explore in the phenology learning activities it is recommended that they conduct some of the seasons learning activities first. Teachers can determine, based on the background of their students, which of these activities would most benefit their students. However, each activity is designed to be conducted independently of any of the other activities.

The phenology protocols ask students to gather some data that they may not be familiar with. Many of the phenology learning activities introduce the terminology and concepts required to do the phenology protocols properly. Therefore, it is recommended that some of the phenology learning activities be done before students begin to follow the phenology protocols. The protocols and the corresponding recommended learning activities are shown in the table below.

## *Design of Visualization Learning Activities*

Each of the seasons and phenology learning activities that utilize visualizations (learning activities S5, S6, P6, and P7) has the same basic organization. First, the teacher provides background for students in a class discussion. Teachers often use this discussion period to elicit initial student ideas, linking the activity to students' experiences. Teachers may also decide to demonstrate the more difficult parts of the small group activity. Next, students break into small groups to further investigate the concepts, guided by a Work Sheet. During small group time, teachers move from group to group, facilitating the activity and checking for understanding.

Materials used in both the class discussion and small groups include the familiar diagrams, tables, graphs, and paper models. Perhaps less familiar to teachers are the use of color visualizations of global data. Against the background of an outline map projection, Earth systems data such as incoming solar energy, temperature, and vegetation vigor are represented as colors. These color visualizations are used to detect patterns in the data and to suggest questions that students can explore. The GLOBE *Earth as a System* poster has good examples of the type of color visualizations used in these activities.

After students have worked in small groups, the class comes together again to deliver their group results. Student assessment can be conducted through several means. One is the Student Work Sheet, for which rubrics are given. Another is the teacher observation of student work during small group time. Finally, students may demonstrate their understanding of the activity during their group presentation.

## *Relationship of Learning Activities to Protocols*

| Protocol | Learning Activity | Recommendation |
|---|---|---|
| Pre-green-up protocol | *Green-up Cards* | Required |
| Pre-green-up protocol | *Sneak Preview of Budburst* | Required |
| Pre-green-down protocol | *Cloud Estimation* (Atmosphere Chapter) | Required |
| Concurrent with green-up or green-down | *A First Look at Phenology* (refers to Land Cover Leaf Classification) | Strongly Recommended |
| Post-green-up or Post-green-down | *Beginning Look at Photosynthesis: Plants Need Light* | Recommended |
| Post- green-down | *Investigating Leaf Pigments* | Recommended |

## Alignment to Other GLOBE Learning Activities

### Alignments for Seasons Learning Activities

The learning activities listed below reinforce the concepts presented in the seasons learning activities.

*GLOBE Earth System Poster Activity Guide*

This poster provides an excellent table that allows solar energy visualizations to be compared with visualizations of other variables, including average temperature, cloud cover, precipitation, soil moisture, and vegetation vigor. The *Activity Guide* will help students understand what they are looking at.

**Atmosphere Investigation:** *Making a Sundial*

Students construct a sundial and use it to observe the movement of the sun through the sky over the course of a day by marking changes in the position of the shadow once each hour. Students determine the approximate time of solar noon at their school as indicated by the time of the shortest shadow. Students revisit the site on a subsequent day to estimate the time of day using their sundial.

## Alignments for Phenology Learning Activities

All the activities listed below reinforce the concept of phenology (response of plants to seasonal and climate change) and the interdependence of the different components of the Earth system.

**Atmosphere Investigation:** *Estimating Cloud Cover: A Simulation*

Students learn to estimate the percentage of cloud cover.

**Land Cover/Biology Investigation:** *Land Cover Sample Site Protocol*

Students learn to use a hierarchical classification system to assign a MUC class to their land cover sample sites.

**Land Cover/Biology Investigation:** *Odyssey of the Eyes: Intermediate, Advanced*

Students learn how a satellite sensor relays information to the computer.

**Land Cover/Biology Investigation:** *Leaf Classification*

Students learn to classify using leaves from their local environment.

**Land Cover/Biology Investigation:** *Site Seeing: Beginning*

Students use quantitative and qualitative observation techniques to investigate their 30 m x 30 m Study Site.

**Hydrology Investigation:** *Water Detectives*

Students use five senses to observe characteristics of water bodies.

**Soil Investigation**: *Just Passing Through*

Student examine the water holding capacity and filtering ability of soils with different properties which may affect plants.

## Alignment for Use of Seasons and Phenology Learning Activities that Utilize Visualizations *(S4, S5, P6, P7)*

Four of the GLOBE *Seasons* and *Phenology Learning Activities* have students use color visualizations and other data to reason about causes, ask questions, and solve problems. Students will be taking a primarily global view of seasonal phenomena such as temperature, green-up, and precipitation. It is important that students understand how to relate the global and local. Therefore, a sample unit of instruction which can be found in the Teachers *Implementation Guide — Earth as a System: First Impressions Describing Earth,* will be useful activities in helping students connect the global phenomena they encounter with their experiences on the ground.

The seasons and phenology learning activities that use visualizations also rely on students' understanding how to interpret color visualizations. Therefore, the activities in the Atmosphere Investigation that focus on learning how to use visualizations in solving problems are useful. One is *Draw Your Own Visualization,* which teaches the basic components of a visualization; its purpose, the chosen color scheme, the data and units, and the underlying geography and scale. A second helpful learning activity is *Learning to Use Visualizations: An Example with Elevation and Temperature,* which employs color visualizations

in problem solving. Students learn to identify important patterns in a color visualization. They also explore the relationship between two variables using color visualizations.

## Student Learning Goals and Alignment with National Science Education Standards.

### Student Learning Goals

The learning activities in the seasons and phenology section target aspects of science learning: content knowledge (particularly in the areas of seasonal change and phenology) and the skills of scientific inquiry.

In the seasons learning activities, students investigate regional temperature patterns and then look at the causes of seasonal change, considering issues such as Earth's tilt, its rotation around the sun, and resulting patterns in the incoming solar radiation as experienced in the different hemispheres. In the phenology learning activities, students are introduced to the basic concepts of budburst, photosynthesis, and pigmentation at the local scale; they look at relationships among ecosystems, environmental factors, and resulting patterns of green-up and green-down at the global scale.

Throughout the activities, students build skills in the use of the tools and processes of scientific inquiry. Many of the activities, for example, use *visualizations* as tools to support description and analysis of complex scientific data. Frequently, students are asked to investigate patterns using data from multiple sources or in multiple representations (ranging from color visualizations to graphs to physical models) and to draw conclusions based on their analysis. Students also develop skills in evidence-based reasoning and in presenting scientific arguments to their classmates.

*Alignment with National Science Education Standards addressed by each of the Seasons and Phenology Learning Activities:*

National Science Education Standards (NSES) offers valuable guidelines to teachers across the country. Such standards furnish teachers with what the science community currently believes are the important ideas in science, hopefully encouraging the exploration of connections and key concepts rather than the memorization of facts.

The following table indicates the particular National Science Education Standards addressed by each of the *Seasons* and *Phenology Learning Activities.*

## Student Learning Assessment

Assessment rubrics are included at the end of many of the seasons and phenology learning activities. These can be used by the teacher to determine the extent to which students have understood the concepts and mastered the skills that were examined or used in the activity and to identify where there is still confusion. The assessments can also be used by students to help them reinforce what they have learned and to identify areas of weakness.

## *Coverage for Seasons and Phenology*

| National Science Education Standards | Learning Activity | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | S5 | P1 | P2 | P3 | P4 | P5 | P6 | P7 |
| **Earth And Space Sciences** | | | | | | | | | | | | |
| **Changes in Earth and Sky (K-4)** | | | | | | | | | | | | |
| Weather changes from day to day and over the seasons | ■ | ■ | ■ | | ■ | | | | | | ■ | ■ |
| Seasons result from variations in solar insolation resulting from the tilt of the Earth's rotation axis | ■ | ■ | ■ | ■ | ■ | ■ | | | | | ■ | ■ |
| **Energy in the Earth System (9-12)** | | | | | | | | | | | | |
| The sun is the major source of energy at Earth's surface | ■ | ■ | ■ | ■ | ■ | | ■ | | | | ■ | ■ |
| Solar insolation drives atmospheric and ocean circulation | ■ | ■ | ■ | ■ | ■ | | ■ | | | | | |
| **Earth in the Solar System (5-8)** | | | | | | | | | | | | |
| Sun is major source of energy for phenomena on Earth's surface | | | | ■ | ■ | | | | | | | |
| **Geochemical Cycles (9-12)** | | | | | | | | | | | | |
| Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere) | | | | | | | ■ | | | | | |
| **Physical Sciences** | | | | | | | | | | | | |
| **Energy: Transfer and Conservation (5-8)** | | | | | | | | | | | | |
| Heat energy is transferred by conduction, convection and radiation | | ■ | ■ | | ■ | | | | | | | |
| Heat moves from warmer to colder objects | | ■ | ■ | | ■ | | | | | | | |
| Sun is a major source of energy for changes on the Earth's surface | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | ■ | ■ |
| Energy is conserved | | | | | ■ | | | | | | | |
| **Chemical Reactions (9-12)** | | | | | | | | | | | | |
| Chemical reactions take place in every part of the environment | | | | | | | ■ | | | ■ | | |

## *Coverage for Seasons and Phenology* *(continued)*

| National Science Education Standards | Learning Activity | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | S5 | P1 | P2 | P3 | P4 | P5 | P6 | P7 |
| **Life Sciences** | | | | | | | | | | | | |
| **The Characteristics of Organisms (K-4)** | | | | | | | | | | | | |
| Organisms can only survive in environments where their needs are met | | | | | | | ■ | | | | ■ | ■ |
| Earth has many different environments that support different combinations of organisms | | | | | | ■ | | ■ | | | ■ | ■ |
| **Organisms and their Environments (K-4)** | | | | | | | | | | | | |
| Organisms' functions relate to their environment | ■ | | | | | ■ | ■ | ■ | ■ | | ■ | ■ |
| Organisms change the environment in which they live | ■ | ■ | | | | ■ | ■ | | | | | |
| Humans can change natural environments | | | | | | | | | | | ■ | ■ |
| **Life Cycles of Organisms (K-4)** | | | | | | | | | | | | |
| Plants and animals have life cycles | ■ | | | | | ■ | | ■ | ■ | | ■ | ■ |
| **Structure and Function of Living Systems (5-8)** | | | | | | | | | | | | |
| Ecosystems demonstrate the complementary nature of structure and function | | | | | | | | | | | x | x |
| **Regulation and Behavior (5-9 & 9-12)** | | | | | | | | | | | | |
| All organisms must be able to obtain and use resources while living in a constantly changing environment | ■ | | | | | ■ | ■ | | ■ | | ■ | ■ |
| **Populations and Ecosystems (5-8)** | | | | | | | | | | | | |
| All populations living together and the physical factors with which they interact constitute an ecosystem | | | | | ■ | | | | | | | |
| Populations of organisms can be categorized by the function they serve in the ecosystem | | | | | | ■ | | | | | ■ | |
| Sunlight is the major source of energy for ecosystems | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | ■ | ■ |
| The number of animals, plants and microorganisms an ecosystem can support depends on the available resources | | | | | ■ | ■ | | | | ■ | ■ | |
| **The Interdependence of Organisms (9-12)** | | | | | | | | | | | | |
| Atoms and molecules cycle among the living and non living components of the ecosystem | | | | | | | ■ | | | | | |
| Energy flows through ecosystems in one direction (photosynthesis-herbivores-carnivores-decomposers) | | | | | | ■ | | | ■ | | | |
| The population of an ecosystem is limited by its resources | | | | | | ■ | | | | | | |
| Humans can change ecosystem balance | | | | | | | | | | | ■ | ■ |
| **Matter, Energy, and Organization in Living Systems (9-12)** | | | | | | | | | | | | |
| Energy for life derives mainly from the sun | ■ | ■ | | ■ | ■ | ■ | ■ | | | | ■ | ■ |
| Living systems require a continuous input of energy to maintain their chemical and physical organizations | ■ | ■ | | ■ | ■ | ■ | ■ | | | ■ | ■ | ■ |
| **The Behavior of Organisms (9-12)** | | | | | | | | | | | | |
| The interaction of organisms in an ecosystem have evolved together over time | | | | | | ■ | | | | | | |