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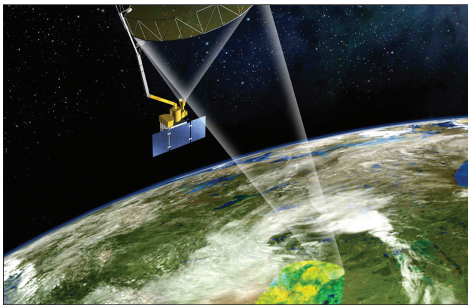

The Breathing Boreal Forest

The vast Northern boreal forest "breathes" so we can all breathe a little easier.

Grade Level
Middle School

Subject Areas
Science, Math, Environmental Science

Duration
Preparation time: 30 minutes-2 hours (to freeze bread)

Activity time:
Warm Up: 5-10 minutes
Part 1: 10-20 minutes
Part 2: 30-45 minutes
Part 3: 20-30 minutes
Wrap Up: 5-10 minutes

Setting
Classroom, schoolyard, park

Skills
Gathering information (observing), Analyzing (identifying components and relationships, comparing, discussing), Interpreting (generalizing, drawing conclusions, relating, identifying cause and effect), Applying (decision making), Presenting (demonstrating, describing)

Vocabulary
Boreal forests, carbohydrates, carbon cycle, carbon dioxide (CO_2), coniferous trees, diurnal, dormancy, drought, fossil fuels, freeze/thaw cycle, frost events, greenhouse gas, hardy, photosynthesis, precipitation, sink, temperate climate, tender

Summary
In this activity students play the role of coniferous trees. First they learn about seasonal freeze/thaw cycles and dormancy through a game of tag. Students then juggle complex environmental factors to try to survive a growing season in a changing climate. Connections between freeze/thaw cycles, photosynthesis and the global carbon cycle are explored.

Charting the Course
Project WET's *Molecules in Motion* activity is a fitting review of the physical states of water and the how they change. Project WET's SMAP *Dirt to Dinner* Activity about soil moisture is a good lead up to this activity, especially Part 3 and 4. Project WET activities are found in the *Project WET 2.0 Curriculum and Activity Guide*. Project WET SMAP activities can be found online at: www.projectwet.org/SMAP.

Objectives
Students will:
- observe that materials containing water are subject to the same physical changes as water (e.g. freezing and thawing).
- demonstrate how seasonal freeze/thaw cycles affect trees.
- discuss that plants exhibit different behaviors/characteristics during growing season than during dormancy.
- analyze the affect of daily frost events on plants.
- explore how temperature and water fluctuation affect growing seasons of plants.
- explore how increased global temperatures affect growing seasons of plants.
- recognize that plants play a major role in the global carbon cycle.

Materials
Warm Up
- Two slices of bread—one normal, one frozen
- Whiteboard
- Marker

The Activity
Part 1
- **Freeze/Thaw Nametags** or costumes (Summer costume could be sunglasses and Winter costume could be hat and gloves)
- Boundary markers (cones, rope, etc.)

Part 2
- Boundary markers (cones, rope, etc.)
- **Tree Cards** (one per student)
- Survivor points—use small numerous objects such as paper squares, bright beads, poker chips, or noodles (you will need up to twelve per student)
- Container for survivor points
- **Spinners**
- Pencil
- Large paper clip
- **Growing Season Chart (15 Days)**

Part 3
- All materials from Part 2
- **Growing Season Chart (17 Days)**

Boreal forest covers vast reaches of Earth's Northern latitudes. PHOTO CREDIT: Artpilot/iStockphoto

Wrap Up

- **Global Carbon Cycle** diagram
- **Atmospheric CO2 Concentration** diagram

Making Connections

Relatively tiny amounts of water in soil make it possible for plants to grow on our planet. A few degrees difference in temperature can mean the difference between frozen and liquid water and can drastically affect how plants grow. The role of plants is larger than we may imagine—impacting the very air we breathe.

Background

Water changes states—from solid, to liquid, to gas—as temperatures fluctuate. We often visualize this as ice, liquid water and water vapor. When water is contained inside another material it is still subject to changes in state with change in temperature, and these state changes can affect the properties of the material. For example, when outside temperatures drop below freezing, water inside plants and soil freezes, halting processes that require liquid water. When temperatures warm up above freezing again, the water contained in plants and soils melts and the plants and soil thaw out again. Throughout the year, in **temperate climates** (climates that vary significantly from winter to summer), annual **freeze/thaw cycles** occur seasonally (winter/summer), but **frost events** (warm days, freezing nights) can also occur **diurnally**—on a daily basis. This activity will explore the impacts of seasonal freeze/thaw cycles and daily frost events on soil, plants and global systems.

Soil is comprised of four components—mineral material, organic material, air and water. Water in soil is extremely important to plant growth. When this water freezes, it becomes unavailable to plants and limits growth. (See Project WET SMAP *Dirt to Dinner Activity* to further explore water in soil.)

Plants need the right amount of water to survive and grow—not too much and not too little. Plant tissue ranges from about 45 percent water (for woody parts such as tree trunks), to 95 percent water (for leaves). Plants get the water they need by absorbing it through their roots. The amount of water available to a plant can change depending on the temperature and precipitation, and these factors change throughout the growing season.

The amount and type of **precipitation** (rain, hail or snow) can affect plant growth. Floods bring excess water and can damage or kill plants. **Drought** (extended period of below-average precipitation) conditions might not provide enough water for plants to grow.

When temperatures drop below freezing, the water contained in plant tissue is subject to freeze. The amount of damage done to some plants by freezing temperatures depends on the type of plant (including where it normally grows and the temperatures it is used to), the age of the plant and the speed, degree and duration of the temperature drop. For some plants, one night when temperatures dip below freezing could kill the plant entirely, for example, citrus trees, avocado trees, succulents and bougainvillea. Other plants, for example trees such as **coniferous** trees (evergreen trees, like spruce or pine) that live in temperate climates have evolved the ability to become dormant to survive the winter. **Dormancy** means the plant's processes slow almost completely. When temperatures rise again snow melts, water in the soil melts and water in the trees melts causing liquid water to be available again. Plants that have been dormant "wake up" again and start to grow.

Warm temperatures also affect plants because as water heats up it evaporates more quickly. High temperatures can remove water from both the soil and plant tissue.

Growing season refers to the period of time that plants are able to grow. In warm climates, plants may be able to grow year round. In temperate climates, growing season is the time between the spring thaw and the fall/winter freeze. During the growing season, plant processes such as **photosynthesis** (the process through which green plants produce sugar for energy) occur.

Periods of transition occur as seasons change. For example, trees do not go into, or come out of dormancy overnight. Freezing or thawing first affects their leaves (or needles), then branches, then trunks and finally the soil over a period of one to three weeks. During these transition times, days are warm with thawing conditions during the afternoon and nights are cold with frozen conditions in the morning. A frost event occurs when vegetation is thawed and trees are growing and then suddenly temperatures drop below freezing potentially damaging the vegetation. In the spring, plants may start to grow during the

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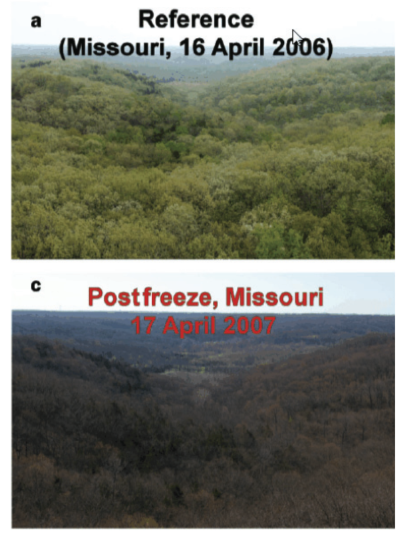
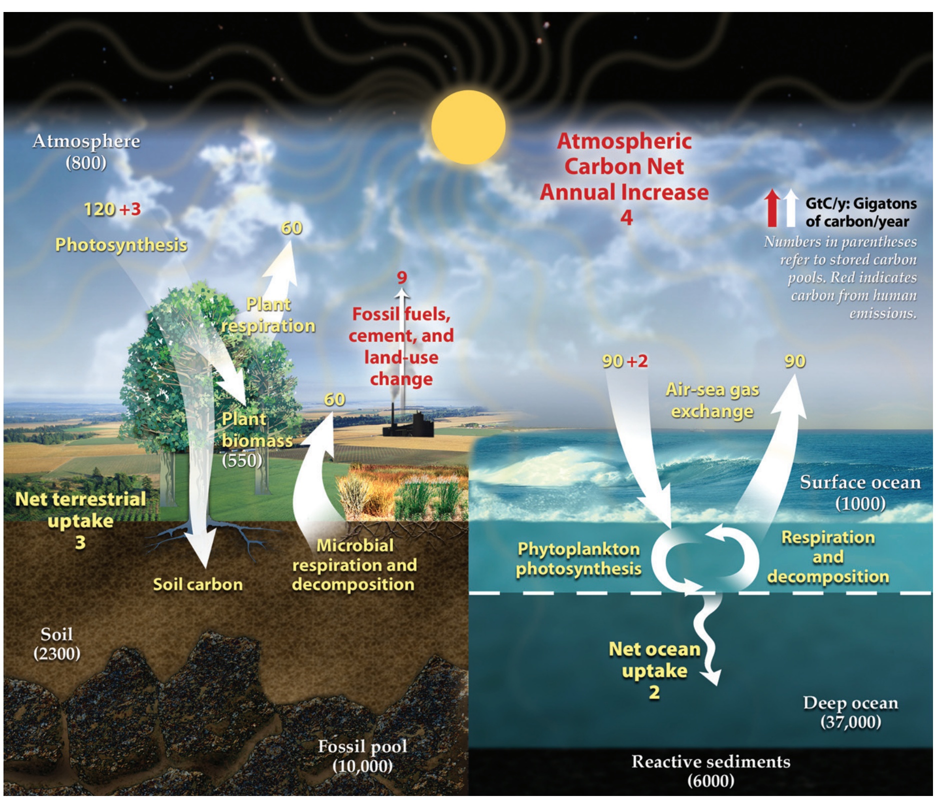
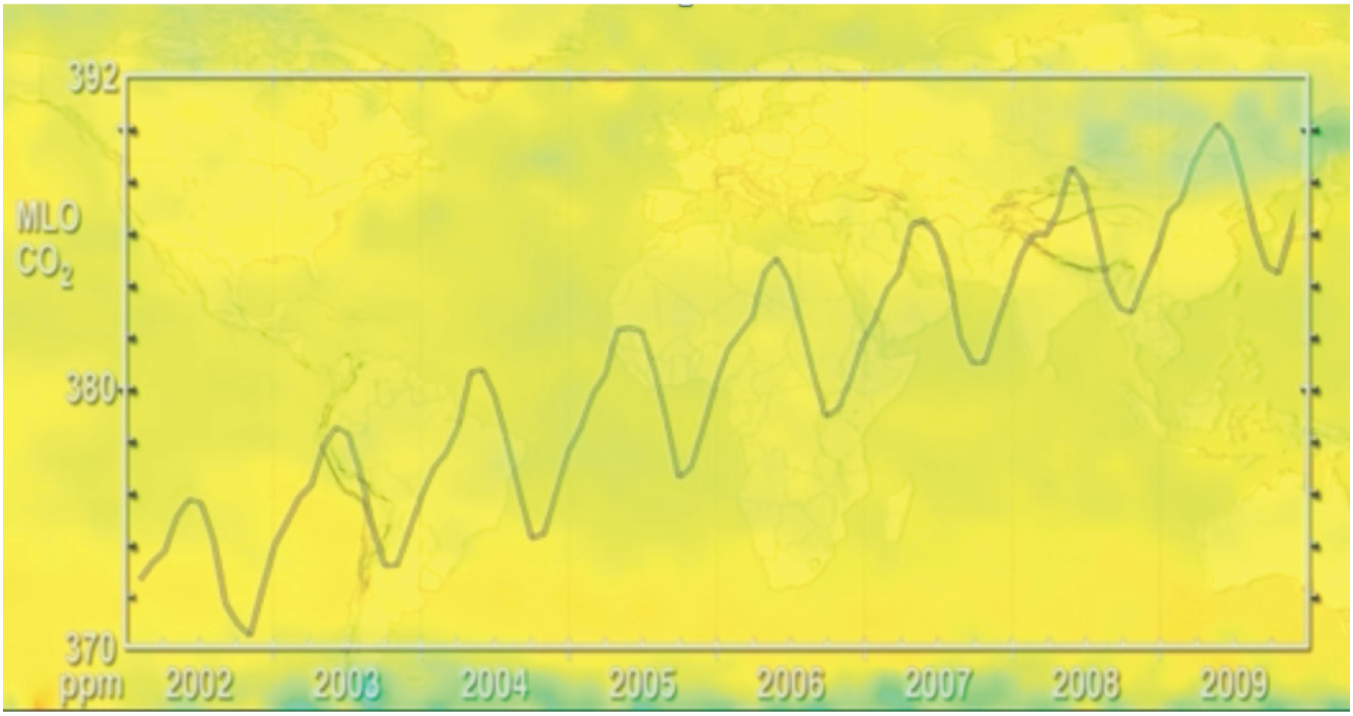


warm days only to be subjected to freezing temperatures at night. Plants are extremely vulnerable to frost events at the beginning of the growing season. New buds and flowers are their most vulnerable parts. These frost events can destroy new growth and lead to a year with no fruit or flowers, or kill plants and ruin crops entirely. For example, the first photo above was taken in Missouri in 2006 and then on the same date one year later in



The Global Carbon Cycle.

PHOTO CREDIT: U.S. DOE. 2008. Carbon Cycling and Biosequestration: Integrating Biology and Climate Through Systems Science; Report from the March 2008 Workshop, DOE/SC-108, U.S. Department of Energy Office of Science (genomicscience.energy.gov/carboncycle/).



This graph shows how concentrations of carbon dioxide in the atmosphere change seasonally due to photosynthesis in boreal forests.

CREDIT:

2007 after a very fast and cold frost event that occurred.

The start of the growing season marks the beginning of photosynthesis, which occurs throughout the growing season until the plant becomes dormant again in the fall. During photosynthesis **carbon dioxide (CO_2)** (a colorless gas comprised of one carbon and two oxygen atoms) is absorbed from the atmosphere and combines with water (H_2O) and, driven by sunlight, produces **carbohydrates** (sugars), which provide food for plant growth and oxygen (O_2) which is released to the atmosphere.

CO_2 + H_2O + sunlight >> carbohydrates + O_2

When measured on a global scale, the impact of the removal of CO_2 from the atmosphere by plants during the growing season becomes evident. Plants play a role in the **carbon cycle**—the cycling of CO_2 in our atmosphere. For example, **boreal forests** (huge forests of coniferous trees mainly located in the Northern Hemisphere) act as carbon **sinks** (materials that absorb and remove carbon from the atmosphere) during the growing season, which helps moderate the overall amount of CO_2 in the atmosphere naturally. The above graph shows seasonal change in levels of CO_2 in the atmosphere as they coincide with growing season for boreal forests in the Northern Hemisphere. It's as if the forests are helping the planet to breathe in and out.

Why does this matter? CO_2 is a **greenhouse gas**. Greenhouse gases are gases that cause Earth's atmosphere to retain heat. More CO_2 in Earth's atmosphere leads to increased global temperatures (also visible on the above graph). CO_2 is added to the atmosphere both through natural processes such as decomposition and ocean gas exchange, and by humans through the burning of **fossil fuels** (coal, oil and natural gas), waste and wood.

How does this all tie together? Temperature trends for approximately the past hundred years (since the industrial revolution) show an increase in global temperatures. Climate change has led to more frost events that have the potential to kill forests. Northern boreal forests play an important role in the global carbon cycle, but increasing frost events threaten their survival. The loss of these trees would mean the loss of an important CO_2 regulating mechanism for our planet.

Procedure

▼ *Warm Up*

- Gather the students and pass around a normal slice of bread. What makes up a slice of bread? (flour, sugar, water, etc.) Does this bread contain water? Explain to the students that although we cannot see liquid water in or on the slice of bread, the plants and materials making up the bread contain water.
- Now pass around a frozen slice of bread. Ask students to make observations about both pieces of bread and list their observations on the board in two columns. Are the properties of the frozen bread the same or different as the properties of frozen water? Does water contained inside a material change the materials properties as temperature changes? Leave the frozen bread out and allow the students to continue to

add to their list of observations as it thaws. (You could also toast the bread to represent very warm and dry conditions and observe changes).

The Activity

Part 1

1. **Explain to the students that water in soil and water in plants is affected by changes in temperature, just like the slice of bread from the Warm Up.** Discuss that temperatures change in both seasonal (winter and summer) and daily (day and night) cycles. Ask students at which temperature water freezes. (32°F).
2. **Ask students to think of properties of soil in the summer (warm, soft, wet, muddy).** List them on the board. Ask students to think of properties of soil during the winter (hard, covered with snow, dry). List them on the board. Ask students to list properties of plants in the summer (you may want to choose a certain type of plant that the students are familiar with) (green, flexible, growing, flowers). Ask students to list properties of plants during the winter (dead, yellow, brittle, dry). Discuss how plants and soil change seasonally.
3. **Explain to students that seasonal freezing and thawing can have an effect on plants.** Do any plants survive the winter? (Yes, imagine trees and lilacs) Do any plants not survive the winter? (Yes, imagine vegetables in the garden that have to be replanted every year).
4. **Explain to students that they are going to be playing a tag game that demonstrates how plant growth can be affected by seasonal freeze/thaw cycles.** The game will demonstrate how plants that survive the winter freeze and thaw—the process of entering and emerging from dormancy. Explain that students will represent coniferous trees for this activity. Ask students what they think happens to this type of tree during the winter. Do they die? Explain that trees become dormant during the winter and their processes slow virtually to a stop.
5. **Set up boundaries for a tag game appropriate for your group size.**
6. **Choose two students to be "it".** One represents Summer and the other Winter (give each student a **Freeze/Thaw Nametag** or costume). Summer is trying to keep as many trees growing as possible, while Winter is trying to keep as many trees dormant as possible. Explain to students that if they are tagged once by winter their needles (fingers) freeze and they must fold them into a fist but can keep running, if tagged again by winter their branches (arms) freeze and they must run around with their arms at their sides. If tagged a third time by winter their trunk (whole body) freezes and they must remain where they are. Summer can "thaw" stationary frozen trees by tagging them several times. If tagged once their needles thaw and they regain the use of their fingers. If tagged twice their branches thaw and they can move their arms, and three times thaws their trunk and they can run around again.
7. **Play several rounds of the tag game so different students can be "it".**
8. **When the game ends, discuss what happened to students as trees.** When winter comes, trees freeze from the outside in (leaves, branches, trunk, soil) and become dormant. As summer starts, they begin to thaw from the outside in (leaves, branches, trunk, soil). These periods of thawing can last a few weeks and are called transition periods.

Part 2

1. **Students now understand seasonal freezing and thawing of trees, and the transition periods in-between.** They will now focus on the growing season of plants and how fluctuations in temperature and precipitation can affect plant growth.
2. **Ask students to think about what happens when spring begins and plants start to grow.** Ask them to list things that could affect plant growth and discuss how each might affect plants (e.g. temperatures—warm and cold, hail, rainstorms, flooding, etc). Ask students if they have ever experienced a warm spring day when temperatures then dropped below freezing at night. They may have seen frost on the grass after a night like this. This is called a frost event. Frost events can occur during and after transition periods as summer begins and ends. Frost events can be very dangerous to plants—especially young plants just starting to grow.
3. **Now ask the students to think of other factors that could affect plant growth as the growing season (summer) continues and discuss how each might affect plants (e.g. hot temperatures, rainstorms, dry conditions).** These factors can also be dangerous to plants.
4. **Just how dangerous environmental changes are for plants depends on the type and age of plant.** The speed, degree and duration of the temperature change and the amount of water available to the plant are also influential.
5. **Explain to students that they are going to be playing a game similar to, but more complicated than "Red Light, Green Light" that demonstrates how plant growth can be affected by various factors during the growing season.**

6. **In the game, students will again represent coniferous trees.** However, not all trees and plants are affected by environmental factors in the same way. Plants that are more **hardy** (capable of surviving harsh conditions), are more likely to survive more frequent, longer and extreme cold or hot temperatures than more **tender** (less capable of surviving harsh conditions) plants. Coniferous trees are hardy plants, but even the same type of plants vary in their ability to survive harsh conditions. Older, more mature plants often fair better than younger plants. Each student will receive a **Tree Card** that will tell them if they will be a young, middle-aged or mature coniferous tree. In this game, different-aged trees have different "survivor powers" based on how hardy they are. The more likely a plant is to be able to survive changing environmental conditions, the more "survivor points" it will start out with. Points are represented by your choice of small objects. Each student starts with six survivor points because coniferous trees are hardy plants. They then receive additional points based on their maturity. For example, a student who is a "mature tree" receives six additional points to start the game with twelve points, whereas a student who is a "young tree" only receives two additional points and starts the game with eight. Based on this system, each student should receive the appropriate number of "survivor points" to use during the game (use of these points is explained in detail below). **Tree Cards** have a tear-off coupon to redeem for the appropriate number of survivor points. Distribute the appropriate number of survivor points to each student (six plus however many their **Tree Card** gets them).

PHOTO CREDIT: bozhdb/iStockphoto

Frost events, especially in the springtime early in the growing season, can be trouble for plants.

7. **Other factors that affect a plant's ability to survive through the growing season include how cold or hot it gets (temperature), how long it stays cold or hot (duration), how fast the temperature changes (speed) and the amount of water available to the plant (which is also affected by temperature).** Different sets of spinners will be used to determine the environmental conditions throughout the growing season.
8. **Set up two boundaries in a large open space (it may take some experimentation to determine how far apart to place the boundaries).** Line the students up along one of the boundaries. Explain that this boundary represents the start of the

growing season—trees have survived their transition period from winter to spring and are ready to grow.

9. **Explain that the other boundary represents the end of the growing season.** The goal is for trees (students) to survive the growing season and make it to the other side.

10. **Explain that you, the instructor, will be announcing the environmental conditions for fifteen days throughout the growing season—five early in the early summer, and ten in the middle to late summer.** Conditions for each day will be determined by several spinners (see **Spinner** pages). The first set of spinners is designed to represent typical early season conditions in a temperate climate when temperatures can fall below freezing at night. If this condition occurs, other spinners are used to determine the speed and duration of the temperature drop. A fourth spinner determines precipitation and water availability. Each factor on a spinner includes directions for students to move forward (grow) or backwards (become stressed). Explain to students that they (trees) will only be able to move forward (grow) when the weather is the right temperature and the right amount of water is available. The plant will be stressed if the temperatures are too hot or cold, or if there is not enough or too much water available. Warm weather will promote growth, however if it gets too hot for too long the tree might become stressed. For each day, the instructor will spin the spinners, announce the instructions and the students will move accordingly. Also, the instructor (or a volunteer) should record each day's conditions on the **Growing Season Chart (15 days)**.

11. **Throughout the game, anytime students are asked to move back, they have the option of "spending" their "survivor points" so that they don't have to move back (or move back as far), thus, taking advantage of the characteristics that make them more hardy.** For example, if the temperature spinner dictates that students should move forward seven steps, and a severe thunderstorm on the precipitation spinners causes them to take three steps back, they can "spend" three "survivor points" and maintain their position. When a student runs out of survivor points he/she must take the step option. If a student steps back far enough to reach the starting line, he or she (tree) has been stressed too much to survive and will not grow anymore during that growing season. Students who are "out" can sit at the starting line or help with the spinners and condition recording. As conditions are established through the spinners, students may raise their hands at any time to cash in "survivor points".

12. **Play fifteen rounds of the game, representing five early summer days and ten mid-late summer days.** Use the Early Summer Spinner set for the first five rounds and the Mid-Late Summer Spinner set for the last ten rounds. Some students should end up back at the start, while others will make it to the end, depending on how all the factors play out.

15. **After fifteen rounds, gather the students to discuss what happened.** Review the conditions from the growing season by referring to the **Growing Season Chart (15 days)**. What factors and conditions affect the growth of plants? (type and age of plant, day and nighttime temperatures, frost events, the speed and duration of below freezing temperatures, precipitation and water availability) What factors help plants survive a growing season? (hardy, mature plants, not too much or two little water, few or no frost events) What factors make it more difficult for a plant to survive through a transition period? (tender young plant, too much or too little water, extreme temperatures, frost events)

14. **Play the game again allowing students to become a different aged-tree for each round.**

Part 3

1. **Increasing temperatures have been recorded all around the planet for many years.** Scientists have seen an overall earlier spring thaw in the northern high latitudes (areas North of 45 degrees North).
2. **To demonstrate this, play the game from Part 2 again, with students in the same tree age roles they just had, but move the beginning boundary further away from the end (to represent a longer growing season).** This time, play seventeen rounds—seven days of early summer and ten days of mid-late summer. Record conditions on the **Growing Season Chart (17 days)**.
3. **At the end of the game gather students to discuss any differences this change might have introduced.**

Wrap Up

- Use the **Global Carbon Cycle** and **Atomospheric CO_2 Concentration** diagrams and what the students learned through this activity to inspire a discussion about plants role in the carbon cycle and how increased global temperatures might affect it.

Assessment

Have students:

- make observations about materials frozen and thawed that contain water and compare and contrast to the physical properties of frozen and thawed water. (**Warm Up**)

- demonstrate the effect of seasonal freeze/thaw cycles on trees. (**Part 1**)
- discuss the concept of dormancy and what it means for plants in relation to seasonal/freeze thaw cycles. (**Part 1**)
- explain what a frost event is and how it can affect plants. (**Part 2 and Part 3**)
- discuss ways in which a variety of factors including plant type, plant age, daytime temperatures, nighttime temperatures, temperature change (speed and duration) and precipitation might affect the growing season of plants. (**Part 2 and Part 3**)
- explore how increased global temperatures affect growing seasons of plants. (**Part 3, Wrap Up**)
- recognize that plants play a major role in the global carbon cycle. (**Part 3, Wrap Up**)

Extensions

Follow weather reports for a temperate location to try to capture real data for daytime and nighttime temperatures, frost events, and precipitation events during a growing season. Watch for news stories or warnings about impacts on plants.

Compare historical weather data to determine if growing season lengths are getting longer for a specific temperate region.

Teacher Resources

Videos

NASA SMAP eClips Videos:

Our World (elementary school level): http://bit.ly/1iXxQ4I

Real World (middle school level): http://bit.ly/18DrZux

Launchpad (high school level): http://bit.ly/IFYOU6Qb

Websites

https://smap.jpl.nasa.gov/

Summer

Winter

Young Coniferous Tree

PHOTO CREDIT: aloha78/iStockphoto

2 Survivor Points

Middle-aged Coniferous Tree

PHOTO CREDIT: Popkov/iStockphoto

4 Survivor Points

Mature Coniferous Tree

PHOTO CREDIT: underworld111/iStockphoto

6 Survivor Points

Young Coniferous Tree

PHOTO CREDIT: aloha78/iStockphoto

2 Survivor Points

Middle-aged Coniferous Tree

PHOTO CREDIT: Popkov/iStockphoto

4 Survivor Points

Mature Coniferous Tree

PHOTO CREDIT: underworld111/iStockphoto

6 Survivor Points

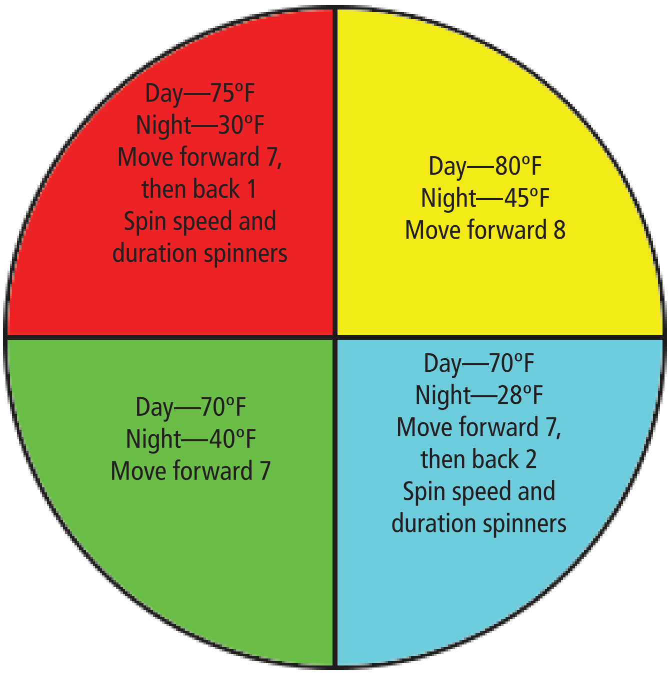
Early Summer Spinners

- Use to determine conditions for first five days.
- Spin 1 and 2 for each day (and record results).
- Use 3 and 4 if directed.

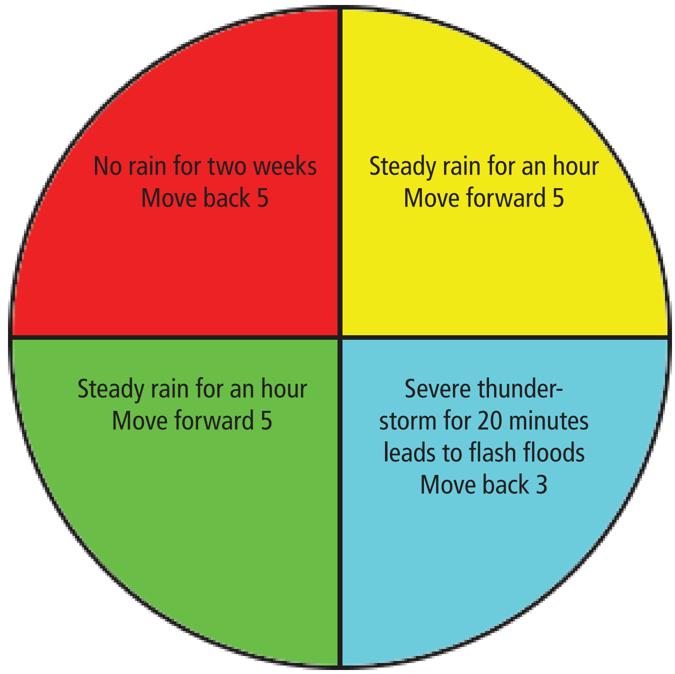
Directions for Spinners

- Lay spinner page on flat surface.
- Place a large paper clip so one end circles the spinner center.
- Hold a pencil verically so that the point is inside the paperclip at the spinner center.
- Flick the paperclip with your finger to spin.

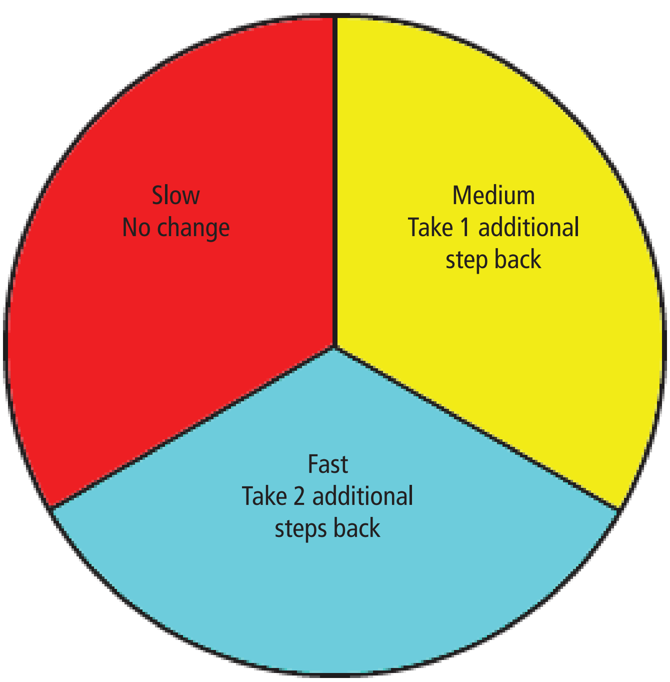
1. Day/Night-time Temperatures



2. Early Summer Precipitation



3. Speed of Temperature Drop

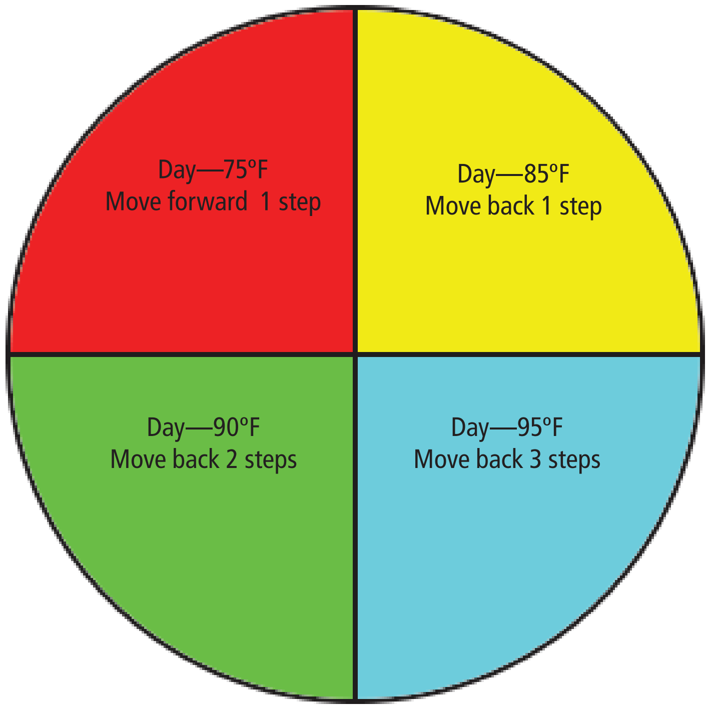


4. Freezing Temperature Duration

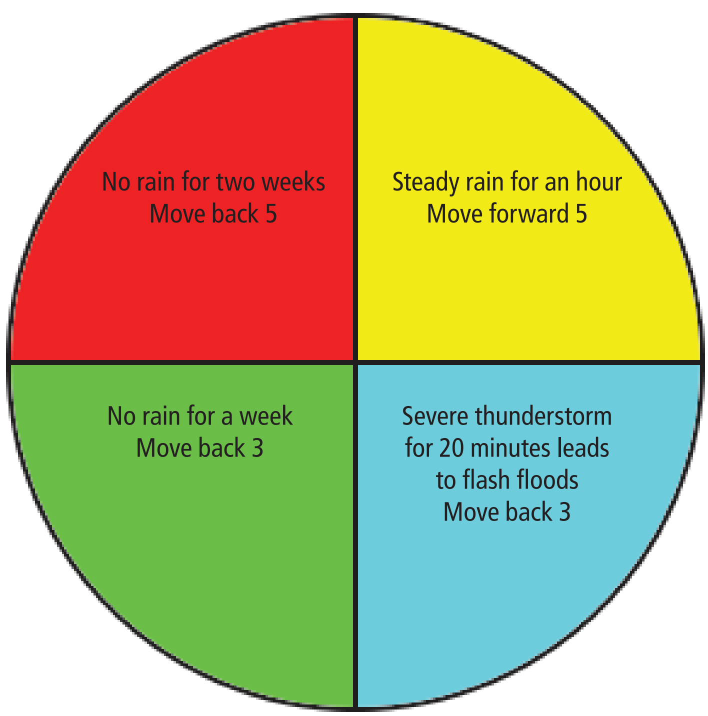
Mid-Late Summer Spinners

- Use to determine conditions for the last ten days.
- Spin and record results for both 1 and 2 for each day.

1. Daytime Temperatures



2. Mid-Late Summer Precipitation

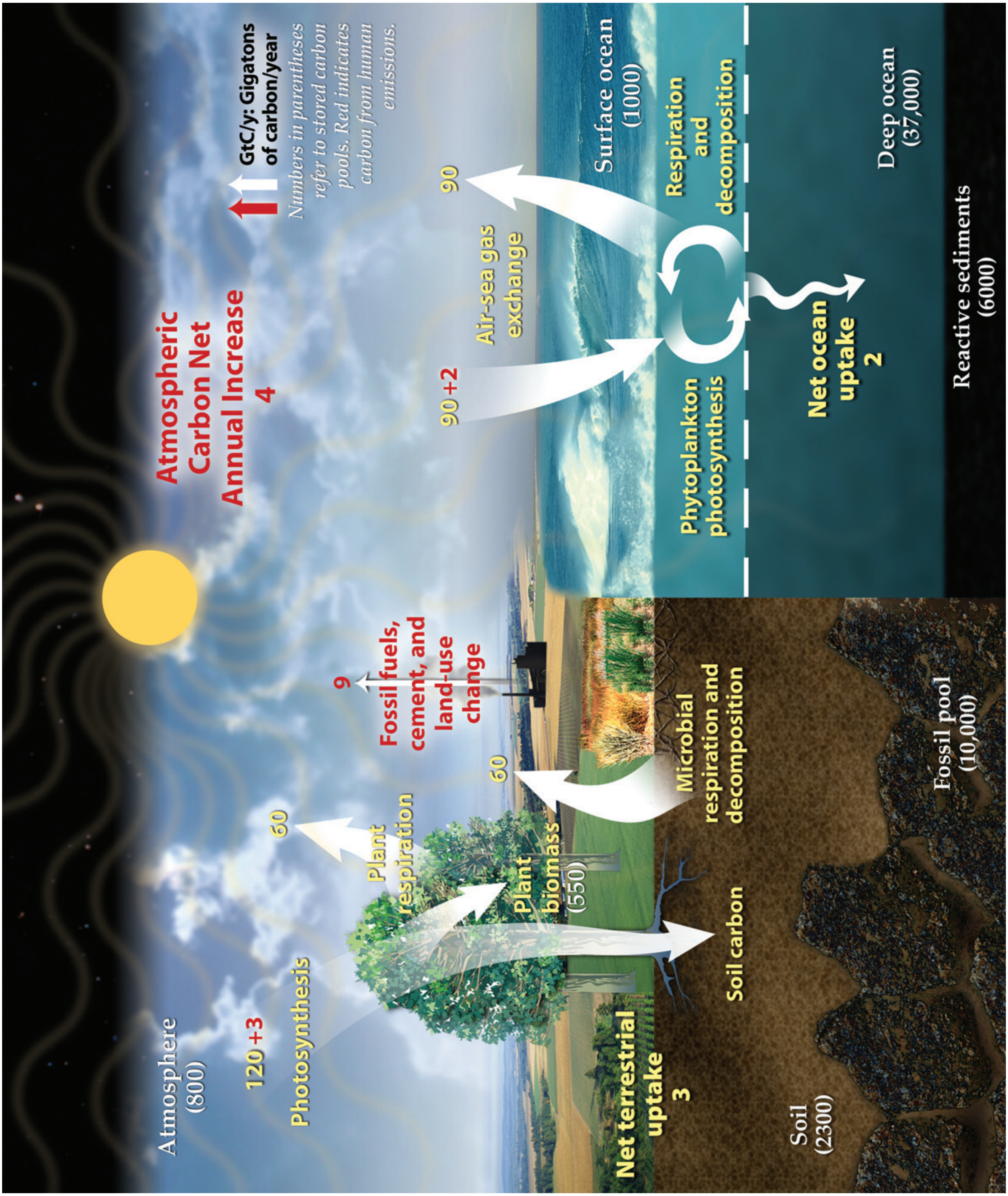


Growing Season Conditions (15 days)

	Day	Daytime Temperature (°F)	Nighttime Temperature (°F)	Speed	Duration	Precipitation
Early Summer	1					
	2					
	3					
	4					
	5					
Mid/Late Summer	6		above freezing			
	7		above freezing			
	8		above freezing			
	9		above freezing			
	10		above freezing			
	11		above freezing			
	12		above freezing			
	13		above freezing			
	14		above freezing			
	15		above freezing			

Growing Season Conditions (17 days)

	Day	Daytime Temperature (°F)	Nighttime Temperature (°F)	Speed	Duration	Precipitation
Early Summer	1					
	2					
	3					
	4					
	5					
	6					
	7					
Mid/Late Summer	8		above freezing			
	9		above freezing			
	10		above freezing			
	11		above freezing			
	12		above freezing			
	13		above freezing			
	14		above freezing			
	15		above freezing			
	16		above freezing			
	17		above freezing			



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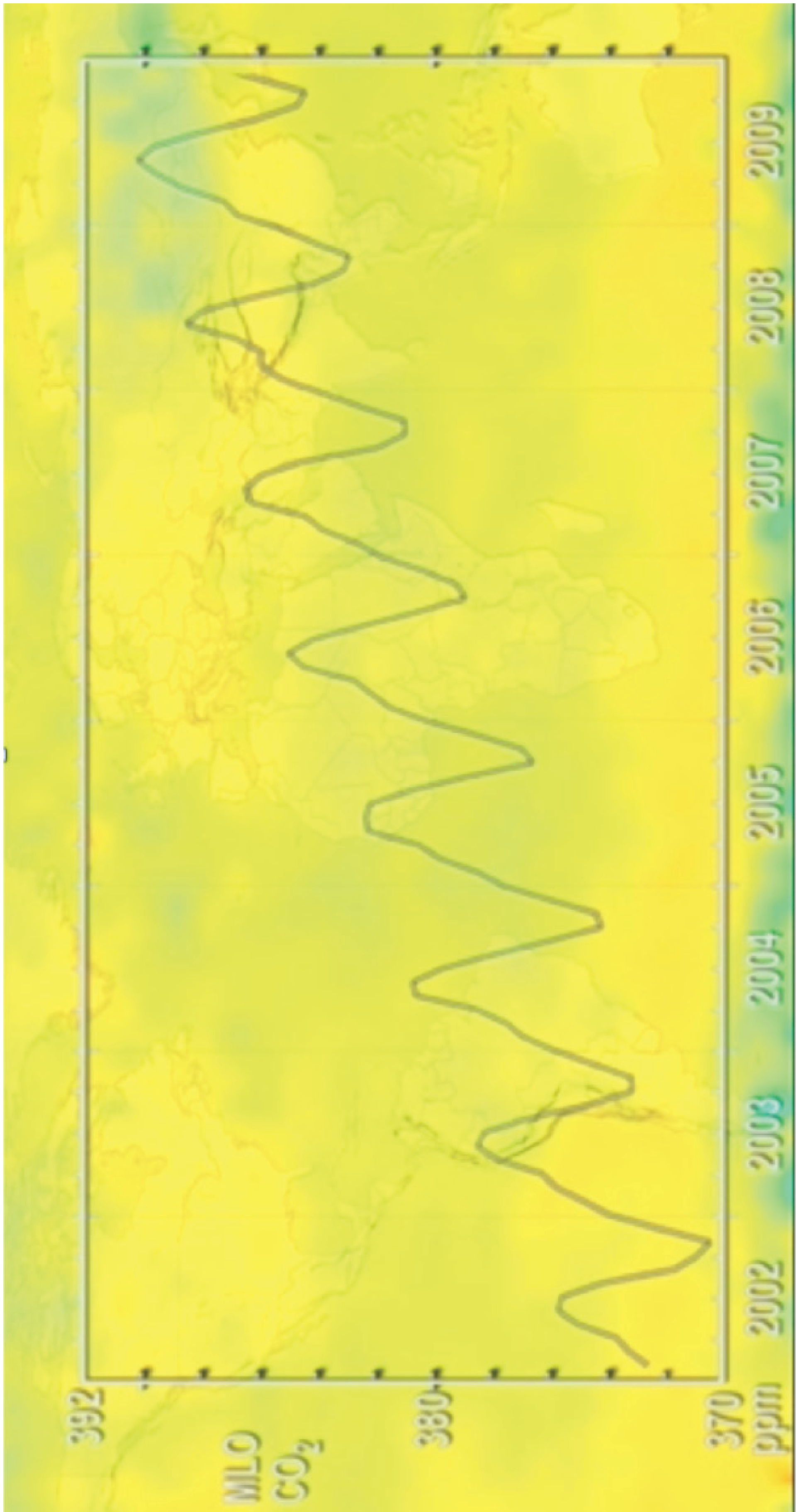
392
MLO
CO_2
380
370
ppm
2002
2003
2004
2005
2006
2007
2008
2009

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