ACTIVITY

3 Atlas of Change

Students use the online resource, the Climate Change Atlas from the United States Forest Service, to explore the effects of climate change on the future distributions of suitable habitats for forest types, tree species, and bird species in the southeastern United States.

Subjects
Agriculture, Biology, Environmental Science, Language Arts

Materials
Student pages and presentations (see Activity Webpage link below); computers with Internet connection; flip chart, poster board, or butcher paper; colored markers or pencils; maps; ruler; scissors; tape or glue sticks; pictures of birds and trees; reference materials

Skills
Communicating, Comparing and Contrasting, Determining Cause and Effect, Interpreting, Predicting

Time Considerations
Three 50-minute periods and homework

Related Activities
Students should have an understanding of climate change (Activity 2) and the relationship between forests and climate (Activity 1). This activity can be followed with additional ways researchers are exploring forest changes (Activity 4) and forest managers are addressing climate change (Activities 5 and 6).

Research Connection
Researchers model climate change and use models to make projections of future conditions. Modeling is an important area of research when addressing complex systems.

Activity Webpage
Find online materials for this activity at https://sfcc.plt.org/section1/activity3

Objectives
By the end of this activity, students will be able to
- Explain how modeling is used to project climate change impacts, and
- Compare projected changes to suitable habitat for southeastern forest ecosystems or bird populations that result from using different climate models and scenarios.

Assessment
- Ask each student to write a summary of the posters responding to this prompt: How might climate change affect forest ecosystems and on what information do we base these ideas? Assess essays for understanding of models; climate; climate change; and range distributions of forests, trees, and bird species.

Background

Projected changes in ***climate***, such as temperature and ***precipitation***, are likely to impact forests in the United States. The trees and animals that are found in forested ***habitats*** may not be able to naturally adapt to rapidly changing climate conditions. As a result, researchers believe that forest ***ecosystems*** in the future will be made up of plants that can thrive in the new climate conditions; these will not necessarily be the same combination of plants that we see now. To help imagine how plants and animals might respond, researchers have created computer ***models*** that combine data from a variety of different factors to project the future climate. Models are tools that use datasets and mathematical equations to approximate processes and ***systems*** over time. They can only include what we know, so they are always being updated and changed.

Additional background information, especially to introduce climate change, can be found in the **Section 1 Overview** and in **Activities 1** and **2**. Some teachers suggest using this activity to begin a unit on climate change.

Climate Change Atlas

Researchers with the United States Forest Service (USFS) are using models to examine the extent of potential ***climate change*** effects on forest ecosystems. Forest Service scientists have combined Forest Inventory and Analysis records for nearly 3 million trees and data on 38 environmental variables (e.g., average annual precipitation, mean July temperature, elevation) in the Climate Change Atlas to predict where a particular tree species or forest type will have suitable habitat by the end of the 21st century (Iverson, Prasad, Matthews, & Peters, 2008).

The Atlas includes information on 134 species of trees in the eastern United States, which are grouped in ten forest type categories and are displayed on maps that can be accessed on the Atlas website. The forest types indicated on the maps are the dominant forest types found in the eastern U.S. There may be other nondominant forest types present in the area, but they are not displayed on the map. The seven forest types found in

Climate change is projected to affect suitable habitat for both tree and bird species, such as this Florida Scrub-Jay in the Ocala National Forest, Florida.

JOHN PUSCHOCK, U.S. FOREST SERVICE

the Southeast are described in the Southeastern Forest Types student page. You can find out more about the trees that grow in your area by talking to ***foresters*** and ***Extension*** agents; visiting an arboretum, park or forest; and accessing tree identification guides and websites (see Additional Resources). The ***biodiversity*** of each forest type depends on the environmental characteristics of that area and the history of disturbance and management in any particular place. As climate changes, the locations of suitable habitat for these forest types will also change. While it is interesting to imagine forests "picking up and moving" to a more suitable habitat, this is not accurate, as each organism may respond differently to climate changes. The amount of movement of a species will depend on where seeds fall and whether seedlings survive. This model shows where the climate will be appropriate for these forests types, not where the forests will be.

The animals that live in these forests will also be affected by climate changes. Many bird species, for example, are closely linked to particular stages of forest development or forest types because of their food and nesting requirements. Much like the forest ecosystems, the habitats of these bird species depend on specific environmental characteristics. Depending on how climate change modifies their habitat, these bird species might flourish or might decrease in population. Thus, scientists correlated 147 bird species with tree species in the Climate Change Atlas to track their relative habitat gain or loss (Matthews, Iverson, Prasad, & Peters, 2011). They used bird population data with 11 environmental variables and tree species potential change data to generate models of current and future suitable habitat.

Global Climate Models and Emission Scenarios

The Atlas relies on a wealth of data that scientists have been collecting for many years. Collecting and assembling existing environmental data is challenging but

TEACHERS SAY...

I thought the Atlas was wonderful. It has a lot of useful info!!

—Ecology Teacher, Virginia

possible, since these factors are observable and measurable. Scientists took records of rainfall, for example, and averaged them over a region to add existing precipitation data to the Atlas. Similarly, scientists sampled tree and bird species in forest plots and established sampling routes used for the North American Breeding Bird Survey to identify and measure the relative abundance of the species. Using such combined data, scientists can develop models of current habitat for tree and bird species.

To estimate how changes in future climate conditions may affect these species, scientists first have to model what those changes might be, which is also a challenge. The Atlas uses three global climate models to project changes to the climate:

1. Parallel Climate Model (PCM)
2. Hadley CM3 Model (Hadley)
3. Geophysical Fluid Dynamics Laboratory (GFDL) Model

These climate models are among the latest generation of numerical models to combine atmospheric, ocean, sea-ice, and land-surface variables to represent historic climate variability and then project future climate changes due to ***greenhouse gas emission*** levels. The three climate models represent a possible range of climate ***projections***, with PCM having a mild degree of change, Hadley having a large degree of change, and GFDL falling in the middle. Because these models use data from large-scale databases and algorithms that reflect global patterns, their predictions of local, specific changes are uncertain. Although the Atlas can be used to suggest potential futures for your state, the models are much better at conveying potential trends across the eastern U.S. They were designed to represent large-scale changes in climate.

Greenhouse gas emissions are important components of our changing climate. However, it is difficult to predict emission levels because such projections depend on national policies and decisions that individual people make. To show the range of possibilities, the Atlas applies two emission scenarios for each model:

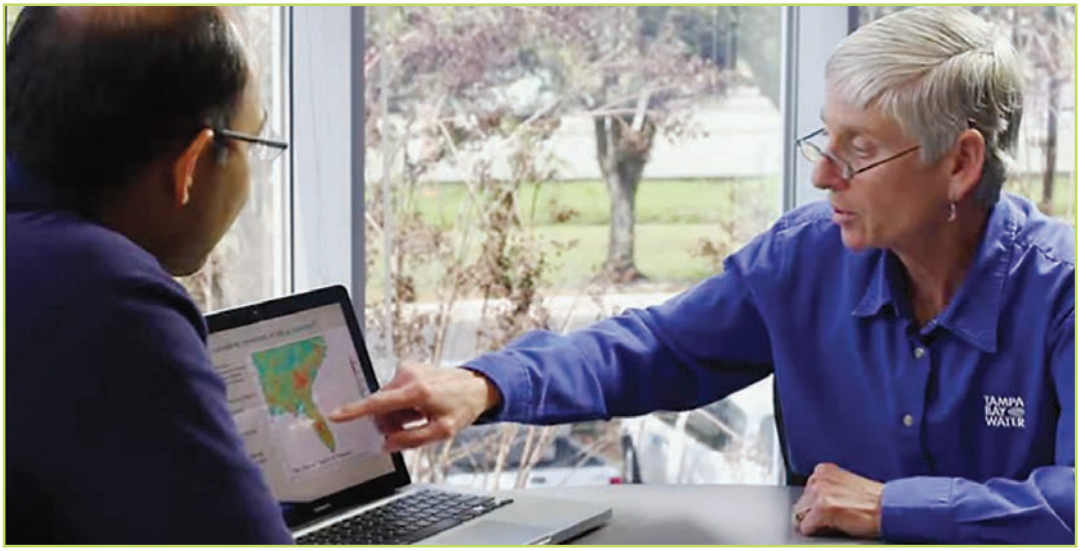
1. High emission scenario, where few ***conservation*** efforts are taken to reduce atmospheric ***carbon dioxide***.
2. Low emission scenario, where significant efforts are taken to reduce atmospheric carbon dioxide.

Generally, the Hadley model under the high emission scenario (Hadley-High) shows a

TEACHERS SAY...

This activity demonstrates effective interpretation of models and how to use the established models.

—AP Environmental Science Teacher, Florida



NOAA CLIMATE PROGRAM OFFICE

Computer models combine data from a variety of different factors to project future climate.

The **Understanding Models** presentation on the Activity 3 webpage will help you introduce models and scientific uncertainty.

potential worst-case scenario (the highest emissions and greatest effects from climate change), while the PCM model under the low emission scenario (PCM-Low) shows a potential best-case scenario (the lowest emissions and therefore least effects from climate change). These two examples can be used to understand the range of possible outcomes. In addition, the Atlas includes results from both emission scenarios using an average from all three models. In total, you can view projected changes in eight combinations of models and scenarios. Based on which models are used as inputs, results for forest types, tree species, and bird species ranges will be impacted accordingly.

When scientists talk about uncertainty, they often use the term differently than it is used in everyday language. ***Scientific uncertainty*** is "the range of values within which the true value is likely to fall" (Understanding Science, 2013). All measurements contain some level of uncertainty. In all climate change models, uncertainty stems from several factors. Models are a simplified version of the world; they are not reality and, therefore, cannot encompass every aspect of a system. Most systems are more complex than scientific models can possibly account for, and interactions among variables can cause minor changes to be amplified over time, resulting in a wide array of model outcomes.

Climate scientists use many techniques to limit and account for uncertainty in their models. For example, they run models multiple times under varying conditions, observing how much the projected outcomes change. They also use different types of models. Confidence in models increases when several different types of models yield similar projections under a variety of conditions. That's why the Atlas has three climate models to explore. The resulting display of forest types shows broad conditions that may exist in the future. The agreement among all the projections represents changes that are most likely to occur.

Teaching This Content

This activity introduces students to tools and models as well as to some of their limitations. Students may express frustration at not having clear and certain predictions about the future, but the uncertainty built into the models also describes the many

Systems Thinking Connection

IN THIS ACTIVITY, students learn how to use a model of a complex system developed by forest and climate scientists. The model incorporates a variety of cause-effect relationships to make projections about how species are likely to be affected by climate change. When cause-effect relationships are simple, we can easily make reasonable projections about their future behaviors. For example, a good outfielder can watch a baseball being hit and move to where it will likely hit the ground. The possibility of wind gusts would introduce some uncertainty—not uncommon to complex systems—that would affect the ball's flight. Without the wind gusts, we can consider the ball and bat a simple system. Simple systems are more predictable because the variables show linear behavior. When behavior is linear, a small perturbation to the system will cause a small effect (i.e., small cause→small effect). For example, hitting the ball slightly harder will send it slightly farther.

However, as a result of their weblike, cause-effect structure, complex systems exhibit nonlinear behavior. With nonlinear behavior, a small perturbation may be absorbed by a system and cause little or no effect, or it may ripple throughout the system, causing an enormous impact. Also, these changes may take place immediately, or there may be a significant delay between a cause and the effects that follow. Consider the difference between poking a tennis ball and poking the person beside you. The distance the tennis ball will move directly depends on how hard you poke it. With the person, however, the possibilities are broader. He or she might ignore you, smile, become annoyed, or have a multitude of other responses that will involve far more outcomes than the tennis ball exhibited. This activity allows students to understand complexity through a climate computer model and see the types of nonlinear impacts that might result. Optional enrichment exercises that use other climate models are available on the Activity 3 webpage.

ways we can influence the future. What will happen depends on what we decide to do.

Students may also recognize that influencing changes in greenhouse gas emissions may require legislation as well as leadership from government and business sectors. A few people riding bicycles rather than driving cars will not make a difference, but changes that a majority of people make will determine if we are in the high or low emission scenario.

While students may feel sad that suitable habitat for some tree and bird species might not be expected to occur in their state in the future, changes in forest ecosystems are simply that—changes. Ecosystems are always changing. People assign value to those changes. Becoming ***resilient*** to future climate changes may mean learning to accept and adapt to ecosystem changes. Complications could arise, however, when people depend on species that no longer thrive in a particular area.

Getting Ready

The Activity 3 webpage provides **Teacher Tools** that you can use to become more familiar with this activity's background and procedure (https://sfcc.plt.org/section1/activity3).

Watch the "An Introduction to Climate Change Atlas: How Does it Work?" video, which is found on the Activity 3 webpage. Other U.S. Forest Service videos are available at www.nrs.fs.fed.us/atlas (see link in right column under Climate Change Atlas Videos). Decide whether your students would benefit from viewing some of these videos; at the least, we recommend the introduction to the Atlas.

Download and review the student pages to familiarize yourself with the Atlas and the activity. Please note that the Atlas websites were being updated in 2014. While the new websites can be accessed online, they are not fully functional yet. For this reason, the student page should be used only with the old website addresses (Tree Atlas: www.nrs.fs.fed.us/atlas/tree and Bird Atlas: www.nrs.fs.fed.us/atlas/bird/index.html). When the new Forest Service Atlas website is finished, we will create a second student page and post it on the webpage for Activity 3.

Download the Understanding Models presentation and review it to determine how much you wish to present to students. This provides an explanation of models, how they are tested, and why they can be different. The Atlas Guide presentation shows screenshots of the Atlas to help you guide students through the website as they complete the student page. This may be easier if you can project the presentation in a computer lab while students work directly with the website. That way they can follow along as you guide them through the site.Make copies of the student pages (one for each student).

Pilot teachers suggested introducing models and the Atlas in a computer lab on Day 1, assigning the WebQuest for homework, developing posters on Day 2, and using Day 3 to review posters and discuss the lesson. If your students cannot complete the WebQuest on their own, you will need another day in the computer lab. Our teachers also found it helpful to use the videos and slide presentations to become familiar with models and the website prior to teaching.

Doing the Activity

1. Remind your students that scientific models are used to represent complex systems. Models share many, but not all, characteristics with the systems they represent. As we learn more about our climate, the models will be improved. Ask students this question: What do you think the impacts of climate change will be on forest ecosystems? Discuss and record their ideas about the

TEACHERS SAY ...

I really enjoyed this and wish I had been able to spend more time on it.

—Ecology Teacher, Virginia

If you used the **Dynamic Systems Dance** from Activity 1, remind students that as one variable changes in a complex system, other variables change too.

TEACHERS SAY ...

The most beneficial measure of my students' understanding was the finished posters. They spent a lot time putting them together.

—Earth Science Teacher, Florida

ecological impacts of climate change so you can revisit them at the end of the activity. Ask students to describe the major types of forests in your state. If they are not familiar with their forests, consider introducing local forests with materials in the Additional Resources section and the Southeastern Forest Types student page.

2. Introduce models and how models are used to simulate processes and systems over time. You may wish to use the Understanding Models presentation on the Activity 3 webpage to do so. Introduce the U.S. Forest Service Climate Change Atlas as an online program that uses models to project potential changes to forest types, tree species, and bird species. As a class, watch the "An Introduction to Climate Change Atlas: How Does it Work?" video from the Forest Service and answer questions students have. You might revisit sections of the video to help clarify any confusion.

3. Explain to the students that they will explore two sections of the Climate Change Atlas to consider current and potential future distributions of tree and bird species habitat in the southeastern United States. Also tell the students that they will use information from the atlases to create a poster of how one type of forest might change over the next century.

4. Distribute one copy of the Atlas Guide student page to each student (or provide a link to access the student page online). Based on computer availability and student ability, decide whether students will work individually or in small groups (two or three students) and whether the Atlas Guide will be completed in class or as homework. Organize students accordingly, review instructions, and ask students to complete the student page. If students need assistance navigating the website, use the Atlas Guide presentation to show them how to use the Atlas; it has screenshots of each step. Both the Atlas Guide student page and Atlas Guide presentation refer to the Tree and Bird Atlases found at www.nrs.fs.fed.us/atlas/tree and www.nrs.fs.fed.us/atlas/bird/index.html, respectively. Caution students to stay on those pages and not to follow the link to the new Atlas.

5. After students have completed both parts of the Atlas Guide student page, explain that they will work in groups to create posters that communicate what they have learned about projected changes to climate and suitable habitat for tree and bird species in their state. Divide the class into five groups. Student groups can use any relevant responses from their completed Atlas Guide student pages, but they will likely need to revisit the websites and explore their specific topics to complete the poster. Each poster should contain important text, graphics, and pictures. Posters can be created on poster boards, butcher paper, or flip chart paper. Students can draw maps by projecting the computer models in the Atlas directly to flip chart paper. A simple reference for helping students make posters, which includes a rubric for grading, is provided in the Additional Resources section (Tips for Creating Informational Posters). Posters should contain the following information:

- ***Group 1: Projected Changes in Temperature and Precipitation.*** Using the Hadley-High and PCM-Low models, describe and compare how temperature and precipitation could change in your state.
- ***Group 2: Current Forest Types.*** Describe each forest type found in your state. Make sure to include common tree species, important forest uses and benefits, and general locations.
- ***Group 3: Projected Changes to Forest Types.*** Using the Hadley-High and PCM-Low models, describe and compare how suitable habitats for forest types in your state are projected to change. Consult with Group 1 so the information you provide does not overlap.
- ***Group 4: Tree Species.*** Describe the tree species that are identified as winners

and losers in your state. Include information about their natural history that might provide clues about why they will thrive or decline in the future climate scenarios.

- ***Group 5: Bird Species.*** Describe the bird species identified as winners and losers in your state. Do these birds require forested habitat for nesting or feeding? (Hint: look at the Life History tab for each bird species description from Cornell Lab of Ornithology, which is available at www.allaboutbirds.org.) How do you think these species might be affected by changes to their habitats?

6. Ask students to put up their posters around the room. Give students time to read each of the other groups' posters.

7. Have a class discussion about the Climate Change Atlas, different forest types in your state, and how forests may be affected by climate change.

- What characteristics make the Atlas a model?
  The Atlas uses data inputs from many sources and provides visual and numeric outputs to project potential changes to tree and bird species based on future climate conditions.
- How does the model address uncertainty?
  By using several different models to provide different projections of future changes.
- In what ways might the climate be different in 100 years?
  In some places, temperatures will be warmer, with less precipitation and drier conditions. Other locations may receive more rainfall.
- Was there a trend in how the different forest types might change?
  Many forest types will shift north and to higher latitudes.
- Which forest types seemed to be affected the most in these models?
  Answers will vary based on the model used. For both the low and high emissions models, forests in the Northeast (e.g., aspen/birch, maple/beech/birch, spruce/fir, white/red/jack pine) are projected to change significantly, with some of these forest types disappearing from the region.
- Are bird species likely to be affected by changes to forested ecosystems? How?
  Answers will vary based on the bird species assessed. Depending on how forest types are projected to change in in the state, suitable habitat for bird species might increase or decrease.
- What do you think the state's forests will look like in 100 years?
  The models in the Atlas are based on the year 2100. However, a change in suitable habitat does not mean that already established trees would immediately die. Due to the long lifespan of trees, these changes will happen over generations of trees, and it is not possible to estimate the exact timeframe.
- What might these changes mean to human communities in your state? Would anyone care if forests are different in the future?
  Forest landowners who rely on harvesting timber for income will care if the trees in their forests are not doing well. In some places, trees may be more resilient to changes than annual crops, so farmers may plant trees instead of cotton, for example.
- How did the different climate models influence the results about projected forest change? Why is this variation important to understand?
  There is inherent uncertainty associated with models, and using multiple models under different future emission scenarios allows us to see the potential range of climate projections.
- If you were a reporter writing a news story about the projections given in the atlases, which model(s) would you discuss in your story? How might your

TEACHERS SAY ...

A student commented: Making the poster was good; it helped me remember what I learned from the Atlas of Change packet.

—Environmental Science Teacher, Virginia

ADRIAN DELGADO, FRIENDS OF THE NATIONAL FORESTS AND GRASSLANDS IN TEXAS

Consider taking your students on a field trip to a forest, park, or arboretum so they can connect their new knowledge with a local ecosystem.

choice affect public understanding about climate change impacts?
Answers will vary. A news reporter who is trying to give an accurate description of the range of potential changes might discuss the differences in the models and the range of projections the models provide. If a news reporter only discusses the models that provide the least or most severe impacts, he or she may give audiences a false impression of climate change effects.

- Systems Reflection: Why are models important tools for systems thinkers?
Systems thinking skills help people to understand the behavior of complex systems. However, Earth's climate has far too many interconnected variables for anyone to keep straight without the help of a computer model. That is why models such as the ones used in this activity are so valuable. Also, models can be great tools for understanding how complex systems behave.

8. Ask students to reconsider their initial ideas about the ecological impacts of climate change (see step 1). Would they change their answers given what they learned by using the Atlas? Summarize the activity by reminding students about the usefulness of models to help us understand complex systems and the relationships among variables such as temperature, precipitation, and tree habitats. They also help us anticipate possible futures. If change is likely, what (if anything) can people do to prepare for it? If change is undesirable, what can people do to prevent it?

Modifications

It may be too challenging for students to understand the nuances among the eight different climate models, but teachers can

dramatically simplify this activity by selecting one to use. Hadley-High will demonstrate the greatest change; the average shows the combination of the models with either the high or low emission scenarios.

Teachers can shorten the WebQuest by skipping the Bird Atlas (Part 2). Posters can be assembled with information from only the Tree Atlas with the first four group assignments.

Find out what scientists and forest managers in your state are doing to learn more about climate, climate change, and impacts to forest ecosystems. The U.S. Forest Service has researchers or national forest staff in all southeastern states. Visit http://www.srs.fs.usda.gov/ to find out more about what is happening in your area.

The **Systems Enrichment Exercises** for this activity allow students to work with models that make projections on a global scale.

Enrichment

Have students identify two tree species found in their neighborhoods and then use the Tree Atlas to explore both species and the potential effects of climate change on suitable habitat.

Organize a poster presentation so that others can view the students' posters. The posters could be displayed at a science night or at some other community event. Ask students to attend and stand by their posters to explain the information and answer questions.

Take a field trip to a local forest, park, or arboretum to explore native forest ecosystems.

Additional Resources

All about Birds
The Cornell Lab of Ornithology
www.allaboutbirds.org
This comprehensive website about birds and bird watching contains lots of information to aid in bird identification.

Dendrology at Virginia Tech (vTree)
John R. Seiler and John A. Peterson
http://dendro.cnre.vt.edu/dendrology/main.htm
This course website provides tree identification fact sheets on over 900 species of trees through a searchable database and map.

Systems Enrichment Exercises

MODELS DESIGNED AT THE GLOBAL SCALE ARE STILL QUITE USEFUL FOR HELPING STUDENTS (and professionals) understand changes in the climate system. In the following exercises, students can work with one or two other models that make projections on a global scale. Both exercises can help students gain greater insight into the time scales involved with international efforts to mitigate climate change impacts.

The **Understanding Climate Momentum** exercise involves the simpler of the two models that students can use. With this model, students can use a slider tool to explore several different possibilities regarding global carbon dioxide emissions, temperatures, and atmospheric carbon dioxide concentrations. This exercise can be found on the Activity 3 webpage.

The **Exploring Climate Models: C-LEARN** exercise allows students to explore how much we need to decrease carbon dioxide emissions in order to stay beneath the Nations' suggested limit of a 2 degrees Celsius (° C) increase over pre-industrial temperatures. This is equivalent to an increase of 3.6 degrees Fahrenheit (° F). Scientists suggest that a global temperature increase beyond this amount will likely cause major disruptions to the world's ecosystems, global food production, and economic development. The lesson is similar to the previous model, but the inputs are slightly more complicated. This exercise can be found on the Activity 3 webpage. Take a look at the short instructional video to learn how to use the model before beginning the exercise.

4-H Forest Resources, Florida Forest Ecology
School of Forest Resources and Conservation, University of Florida
http://www.sfrc.ufl.edu/extension/4h/trees/index.html
This website provides photographs and descriptions of 50 major trees in Florida.

A Climate Change Atlas for 134 Forest Tree Species of the Eastern United States
Anantha Prasad, Louis Iverson, Stephen Matthews, and Matthew Peters; U.S. Forest Service
http://www.nrs.fs.fed.us/atlas/tree
This searchable database provides information on 134 common trees in the eastern United States. The key feature is the presentation of data for each species describing both the current distribution of that species and future suitable habitat based on climate change models.

A handout on the Activity 3 webpage provides helpful tips for designing informative posters.

Tips for Creating Informative Posters
School of Forest Resources and Conservation, University of Florida
https://sfcc.plt.org/section1/activity3
This handout provides helpful information and suggestions for helping students design informative posters.

Climate Modeling 101
The National Academy of Sciences
http://nas-sites.org/climatemodeling/
This website provides information and short videos on climate models and how they are constructed and validated.

How Do Climate Models Work? Koshland Science Museum
https://koshland-science-museum.org/explore-the-science/earth-lab/modeling
This easy-to-understand slideshow uses simple graphics and text to address four main topics: how climate models work, how climate models are tested, what has caused global climate change, and what are the future impacts of climate change.

Southern Forests for the Future
World Resources Institute
www.seesouthernforests.org
This program contains maps, photos, case studies, and other information to highlight key features and trends for southern forests.

Forest Service Southern Futures Project
U.S. Forest Service
http://www.srs.fs.usda.gov/futures/
This website contains the most recent papers on climate change impacts to southeastern forests.

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