



Will the Sap Still Rise When the Mercury Hits New Highs?

A Study of Phenological Events and Climate Change

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Curriculum Program for Middle and High School Students

Written by Melissa Fellows and Jen Stainton
Woodstock Union Middle and High School , Woodstock, VT

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U.S. Department of the Interior
National Park Service
Northeast Temperate Network
Marsh-Billings-Rockefeller NHP

ON THE COVER: A maple tree which has been tapped in the "traditional" way to harvest maple syrup. Photograph by: Oven Fresh

Introduction:



Research has shown that in order for adolescents to care about the natural world and be prepared and willing to solve the complex environmental problems that they are about to inherit, they must be connected to nature through a variety of experiences in nature.¹² Phenology is the study of the timing of biological events. Observing and recording phenological events provides an opportunity for teachers to facilitate important connections between students and the natural world while addressing the all-important standards and grade level expectations simultaneously. The strong tie between altered biological cycles and our changing climate also creates a link between tangible evidence (observations of phenological events) and an abstract, global environmental issue. Phenological events can be observed in rural or urban environments, from classroom windows or the middle of wetlands, and at any latitude. Although this unit focuses on species and relationships common in New England, the activities can be adapted to suit most other locations and conditions.

One of the more defining plant species for Vermont is *Acer saccharum*, the sugar maple tree. With one in four trees in Vermont being sugar maple, the tree's colorful fall foliage adds to the beauty of our region.⁸ And what Vermont resident hasn't enjoyed the tree's spring offering of sap, used to make maple syrup? In 2009, Vermont accounted for 63% of New England's maple syrup production.⁶ This has an economic value of over \$226 million annually for the state of Vermont.⁸



A growing number of scientific studies indicate global temperatures are increasing.⁴ This change in average temperatures and also monthly snowfall has New Englanders concerned about the future of the maple syrup industry. The maple syrup industry is heavily dependent on specific temperatures and snowfall. "A blanket of snow during the winter protects the roots of these trees, making it easier for them to extract soil water when temperatures rise and the sap begins to flow. The latter occurs when the internal tree temperature rises above freezing, which corresponds to air temperatures of 35-40 degrees F."⁷

Phenology is a way to detect a species' response to climate change. Through this unit, students will understand the implications of climate change on ecological as well as economic systems. Students will also graph, interpret, and analyze data on temperature, snow depth, and season length to determine if maple trees and/or the sugaring industry in Vermont are being affected by climate change. Finally, students will conduct year round phenological examinations of maple trees and report their findings. Extensions are provided to assist teachers in other regions of the United States with incorporating phenological topics into their classes.

Unit Objectives: Through the completion of this unit, students will:

1. Understand the importance of the maple syrup industry to Vermont.
2. Read and summarize information in primary and secondary sources.
3. Use technology to construct spreadsheets and graphs of historical data.
4. Interpret and compare sets of data to determine changes in temperature, snow depth, sugaring season length, and potential climate change effects on New England.
5. Communicate findings to the rest of the class.
6. Communicate and defend a scientific argument about the link between temperature, snowfall and sugaring season length.
7. Identify, tap and monitor sugar maple trees, or conduct a phenological study of a local species.
8. Compile phenological data for a web-based database.
9. Develop a method for recording and maintaining long-term data sets.
10. Develop writing and presentation skills.
11. Gain experience in the field.
12. Propose further questions to investigate.
13. Understand the importance of climate change.
14. Understand the importance of citizen scientists and methodologies used for phenological monitoring.

Unit Standards: This unit is designed to be used and modified for grades 7 through 12.

National Science Education Standard (grades 9-12):

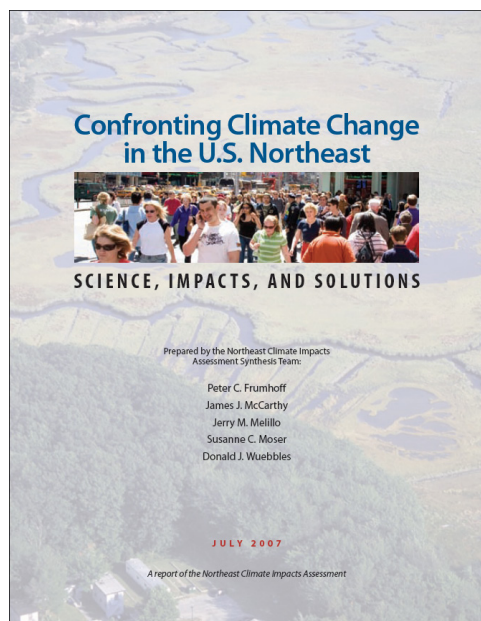
- H.U.2: Evidence, models and explanation
- H.C.4: Interdependence of organisms
- H.C.6: Behavior of organisms
- H.D.1: Energy in the Earth's system
- H.F.3: Natural resources
- H.F.6: Science and technology in local, national and global challenges
- H.G.1: Science as a human endeavor
- H.G.2: Nature of science knowledge

Vermont Science Grade Expectations (grades 7-12) :

- S7-8:1: Scientific questioning
- S7-8:5: Representing data and analysis
- S7-8:34, 36: Interdependence within ecosystems
- S7-8:38: Classification of living things
- S7-8:39: Natural selection and evolution
- S7-8:49: Natural resources
- S9-12:6: Analyzing significance of experimental data
- S9-12:7: Proposing explanations for results
- S9-12:8: Predicting how scientific conclusions can be applied to economic issues
- S9-12:49: Long term changes to natural cycles

Exploration #1:

Collection of Background Information Using Summary Reports



Materials:

Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Prepared by the Northeast Climate Impacts Assessment Synthesis Team of the Union of Concerned Scientists.³

This document is available online in PDF format at the address below: <http://www.climatechoices.org/assets/documents/climatechoices/confronting-climate-change-in-the-u-s-northeast.pdf>. Additional information on this report can be found at www.northeastclimateimpacts.org.

Description:

Exploration #1 serves as an introduction to climate change and the associated impacts on humans and the environment. In order for students to understand the need for phenological monitoring, the connection between increased levels of atmospheric CO² and changes to our ecological systems on which life depends must be made clear. The online text Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions is an excellent source for developing

student background knowledge on the topic of climate change. The text can be incorporated into classes in a number of ways, the following course of study is one suggested approach.

Using The Executive Summary: The summary explains the high and low emission scenarios developed by the Northeast Climate Impacts Assessment Synthesis Team. These scenarios are referred to throughout the remainder of the text and therefore, the summary develops common ground upon which the discussion of climate change can be built.

Using The Remaining Chapters: The remaining chapters of the book can be divided up among student teams. The goal of this activity is to create a clear picture of the projected climatic and ecological future of Vermont and New England over the next 50 to 100 years. Each team becomes an expert on a particular chapter of the report and summarizes it for the rest of the class. Below, each chapter is listed, along with suggested activities tailored to the content in that chapter.

Chapter One: Our Changing Northeast Climate

- Use specific examples to compare and contrast Vermont in 2010 with predictions for 2050, and 2090.
- Create a website (or other presentation) describing Vermont during these time periods.
 - o Average seasonal temperatures
 - o Effects on the hydrologic cycle
 - o Changing seasons

Chapter Four: Impacts on Forests

- Create a map that shows how migratory bird routes and schedules might change over the coming century.
- Design a forest food web for the year 2090.

- o What species would be present? Consider both immigrants and possible extinct species.
 - o How would relationships between organisms change?
 - o How would changing abiotic factors affect food webs?
- Write a timber industry report based on predictions for 2050 and 2090.
 - o Consider movement of plant species over time.
 - o What diseases might be present that would affect timber harvest and timber products?
 - o Examine a local Forest Management Plan for 2010. Write an updated plan for 2050 and 2090 based on climate change predictions. What species would you manage for and why?

Chapter Five: Impacts on Agriculture

- How will the local Farmers' Market based on predictions for 2090 look different than the market of 2010?
 - o What produce will be available and why?
- Estimate the price of a gallon of milk in 2090. Explain why the price of milk has changed over the years.
- Design an experiment that will help scientists understand the potential impact of an invasive species in the late 21st century



Chapter Seven: Impacts on Human Health

- For each of the following individuals, hypothesize which challenges they might face as our climate changes:
 - o A three month old baby living in Burlington, Vermont in 2075
 - o A twelve year old, athletic girl with asthma in 2050
 - o A seventy-two year old man living in his childhood home in a rural town in 2025
- Create hypothetical recommendations from the Centers for Disease Control for vector-borne disease outbreaks, based on predictions for 2060.
 - o Consider which diseases will be most common and explain your thinking
 - o Develop possible prevention strategies

Chapter Eight: Meeting The Climate Challenge

- Imagine that it is Earth Day in 2090. You turn on the radio and hear a public service announcement related to what you can do to reduce greenhouse gas emissions. What does the PSA say?
- Write a letter to your state senator describing what you think Vermont needs to do in order to reach the lower emissions scenario detailed in the report

Exploration #2:

Introduction to Phenology: A Class Discussion

Materials:

Computers with internet access for student use
Digital projector

Directions:

1. Introduce students to the science of phenology by projecting the following definition of phenology on the board: “Phenology is the study of the timing of biological events.”
2. Ask students to think of as many natural events as possible. Examples will vary due to location but may include: first frost, annual bird and butterfly migrations, spring ice out on streams, first snowfall, budding of flowers and trees, sap flow in Maple trees, animal hibernations, and tree leaf out. Note and clarify the difference between phenology (the study of biotic changes) and other abiotic changes (for example, ice out).
3. Show students websites for recording and posting observations about phenological events such as:
 - o USA National Phenology Network: <http://www.usanpn.org/user?destination=MyNPN>
 - o Project Budbreak: <http://budbreak.tc.cornell.edu/>
 - o Project BudBurst: http://www.windows.ucar.edu/citizen_science/budburst/
 - o Journey North: <http://www.learner.org/jnorth/pde/PhenDataAbout.html>
4. Ask students why scientists might be interested in recording data about phenological events. Leading questions could include:
 - o How might scientists use data collected over a number of years?
 - o What would happen if the first frost came earlier or later than usual?
 - o How do animals know when it is time to migrate?



5. Ask students to make a connection between changes in biotic populations and abiotic factors. At this point, clarification of the difference between weather and climate may be necessary. More information can be found on the Project BudBurst website at: http://www.windows.ucar.edu/citizen_science/budburst/climatechange.php
6. Ask students whether plants or animals are more susceptible to climate change. Consider answers and discuss that plants cannot move in response to climate change like some animals can. Ask students if they have ever grown a garden. How do gardeners know when to plant different plants and when to harvest them? This discussion will not be focused on finding a correct answer, instead it will be a way for students to consider which traits of plants and animals will make them better able to survive a changing climate.
7. Relate discussion of phenological events and monitoring to climate change. Discuss the importance of recording and reporting phenological events as the climate changes.

Exploration #3:

Climate Change and the Maple Syrup Industry in Vermont

Materials:

Student copies of articles for Part I
Student copies of historical data sets for Part II
Student copies of “Drawing Conclusions”
Computer with Internet access and spreadsheet program
Overhead projector
Technology teacher/coordinator at your school
Statistics/Mathematics teacher at your school

Directions:

Part I: Hand out one or more of the articles below or create a link to them on your classroom website. Articles 1 and 2 are general news articles, while 3 and 4 are primary research documents. You may choose one or more of the articles based on the class level and interest. Foster small-group discussions of the article by using a discussion protocol from The National School Reform Faculty entitled, “Text Rendering Experience.” For more information on how to facilitate this protocol with your students, go to: <http://www.plcWASHINGTON.org/study-groups/protocols/learning-from-text/text-rendering-experience.pdf>

Articles for Part I:

General News Articles:

- Article #1: “Climate Changing? Uncle Sam Wants Your Observations” <http://www.nytimes.com/cwire/2009/06/23/23climatewire-climate-changing-uncle-sam-wants-your-observ-64119.html> ⁹
- Article #2: “Warm Winters Upset Rhythms of Maple Sugar” http://www.nytimes.com/2007/03/03/us/03maple.html?_r=1

Primary Research Documents:

- Article #3: Duchesne, L., Houle, D., Cote, M.A., Logan, T, 2009. Modeling the effect of climate on maple syrup production in Quebec, Canada. *Forest Ecology and Management*. 258, 2683-2689.
- Article #4: Heinrich, B, 1992. Maple Sugaring by Red Squirrels. *Journal of Mammalogy*. 73, 51-54.

Part II: Creating spreadsheets and graphing data sets for temperature, snow depth and average sugaring season length.

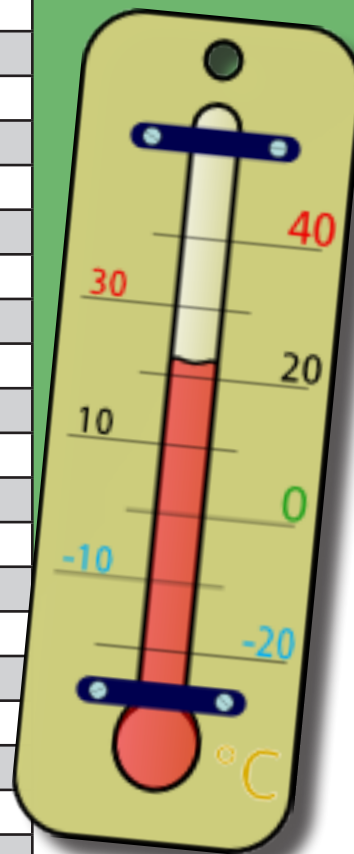
Below you will find sets of data for two time periods: 1963-1986 and 1987-2009. There are data for each of the following factors: average temperature, average snow depth, and average season length. Using copies of the data sets, students will use computers and a spreadsheet or graphing program (like Microsoft Excel) to generate graphs and view the data. It is recommended that students work in pairs, and each pair is given both data sets (all years) for one factor. The pair should focus on making a correct spreadsheet and graph.

Procedure:

1. Become familiar with the spreadsheet and graphing program available for use at your school. Your school or district technology directors are good sources of information.
2. Develop a short tutorial to walk your students through in order to introduce them to putting data into a spreadsheet, and then using the program to create appropriately labeled graphs.
3. Develop hypotheses with the class by asking the following question: “Based on the information you have read about climate change in New England, what do you hypothesize the data will show once you’ve created a graph?” Have students write their hypotheses on the “Drawing Conclusions” sheet (below).
4. Hand out copies of the data sets below to the pairs of students. Assist students in the creation of spreadsheets and graphs of the information in the data sets. See data sets below.
5. When students have finished making their graphs, facilitate their understanding of the information in its graphic representation. Work with the statistics teacher at your school to help students understand the best options for analyzing the graphs. Help the students answer questions like: Is this a significant difference? What is this graph telling you? What happens if you remove the outliers from your data sets? What is an anomaly?
6. Ask students to write a summary sentence of the information the graph provides about the factor on the Drawing Conclusions sheet.
7. Create consultancy groups of six by having one pair for each factor. One group will consist of 3 pairs: temperature pair, snow depth pair, and season length pair.
8. In their consultancy groups, the pairs should show the other members of the group their graph, and share their interpretation of the data.
9. Once all three pairs have shared, the whole group will write a statement about the outcome of the data overall on the Drawing Conclusions sheet.
10. Each consultancy group stands up to share their statement with the whole class.
11. Teacher summarizes the findings for the class.
12. Extensions:
 - Invite a local sugarmaker in to share their life experience with the maple syrup industry and compare their phenological monitoring with student findings from this exploration.
 - Invite a researcher in from the local extension to discuss the findings of this exploration with students

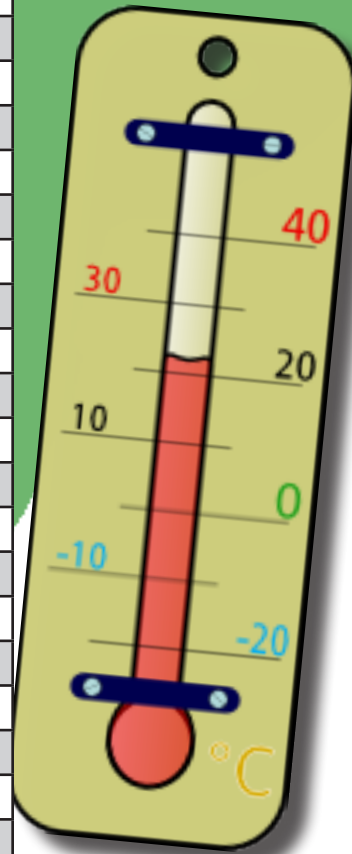
Data Set #1: Average Temperature in Fahrenheit 1963-1986 for the months of January February, March and April in Rutland, Vermont.¹¹

1963	28.75
1964	32.13
1965	28.83
1966	23.4
1967	29.48
1968	29.65
1969	30.45
1970	27.8
1971	27.88
1972	37.2
1973	33.5
1974	30.8
1975	30.5
1976	32.1
1977	31.1
1978	26.4
1979	29.5
1980	49.98
1981	32.1
1982	28.3
1983	32.6
1984	28.9
1985	31.8
1986	32.7

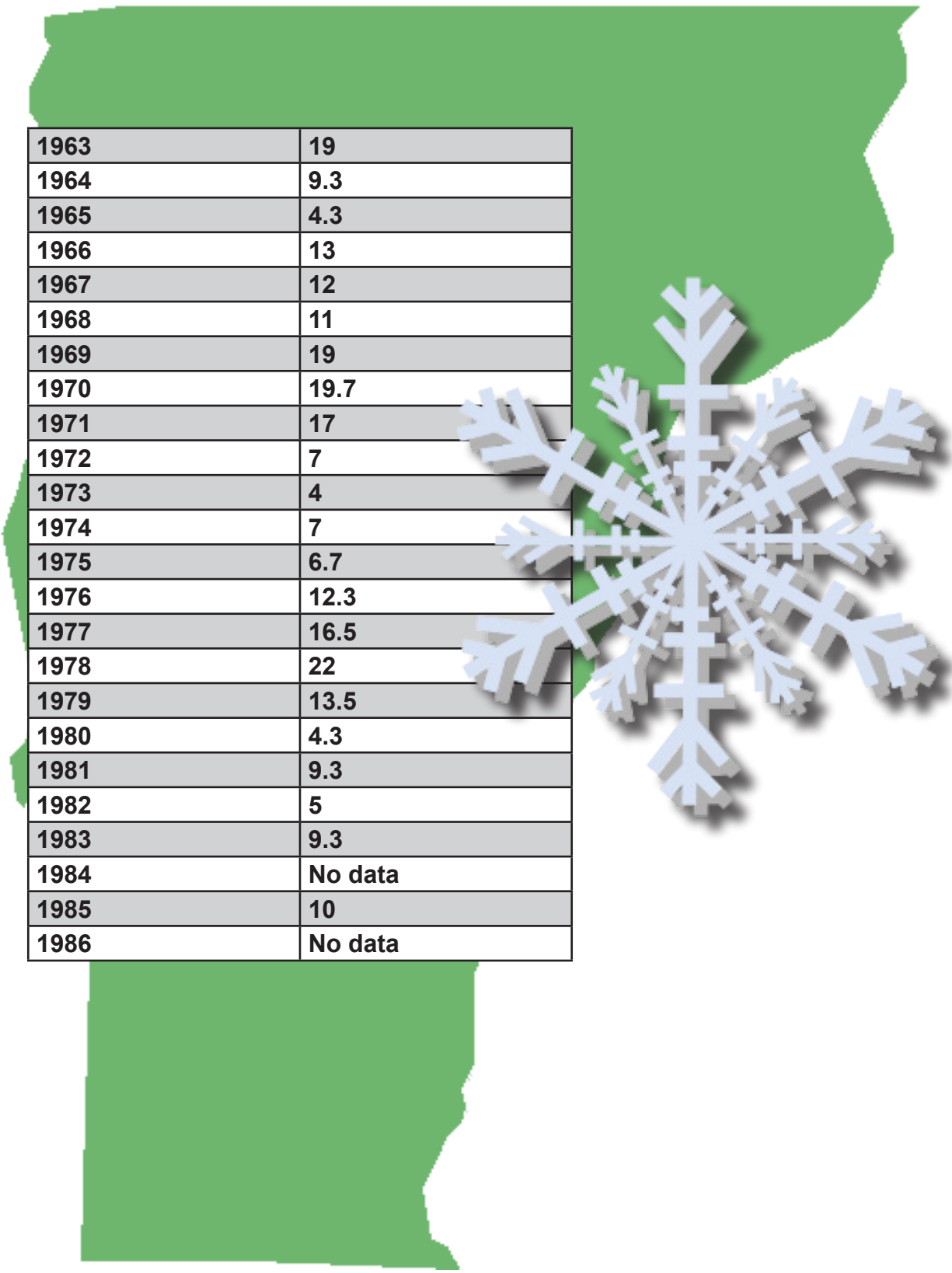


Data Set #2: Average Temperature in degrees Fahrenheit 1987-2009 for the months of January, February, March and April in Rutland, Vermont¹¹

1987	30.6
1988	31.3
1989	30.1
1990	33.5
1991	33.0
1992	29.2
1993	28.5
1994	25.4
1995	31.5
1996	28.75
1997	29.75
1998	34.1
1999	30.9
2000	31.1
2001	30.2
2002	34.6
2003	27
2004	28.9
2005	29.98
2006	33.8
2007	26.8
2008	30.3
2009	27.98

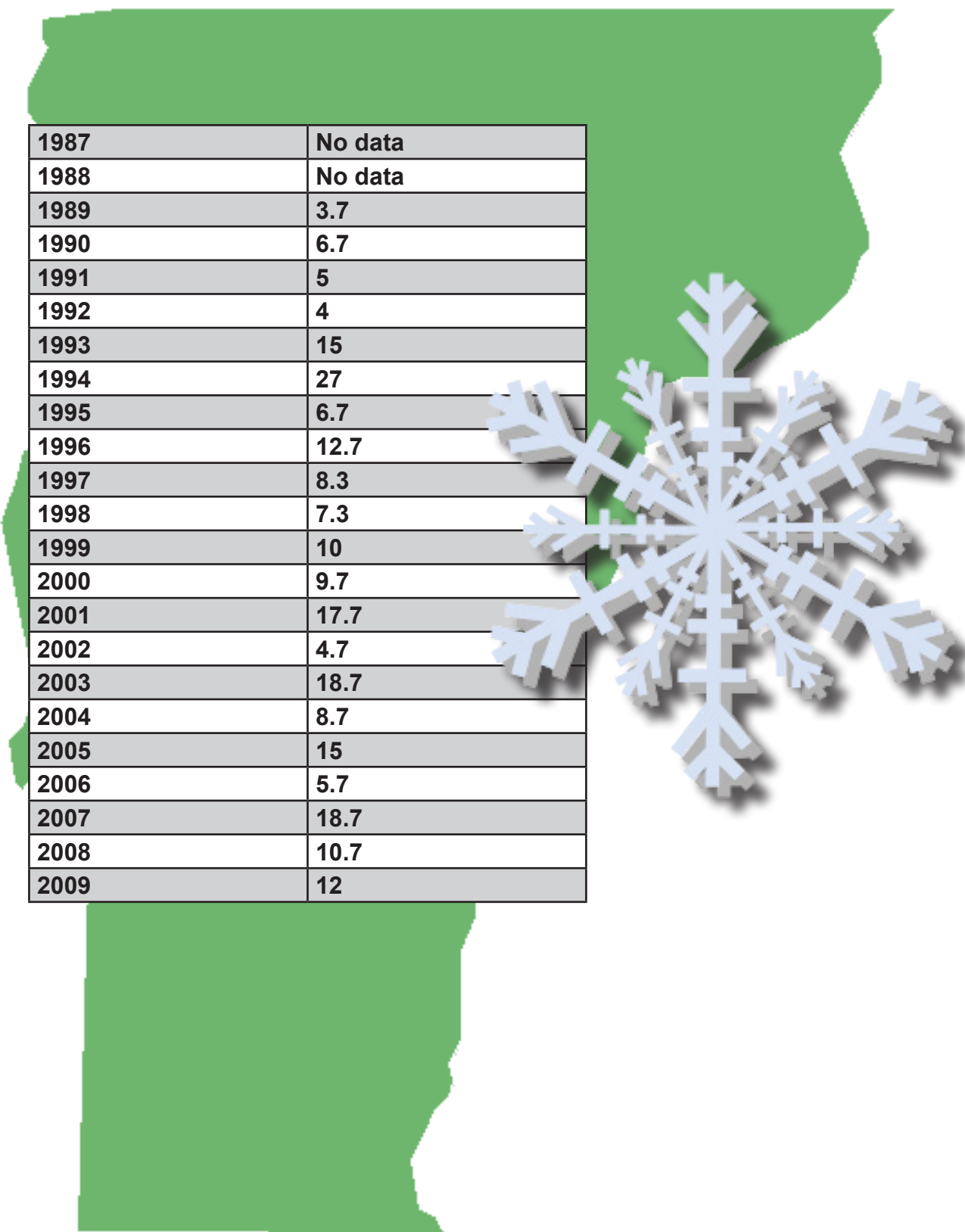


Data Set #3: Average Yearly Snow Depth in inches 1963-1986 for January, February, March in Rutland, Vermont.¹⁰

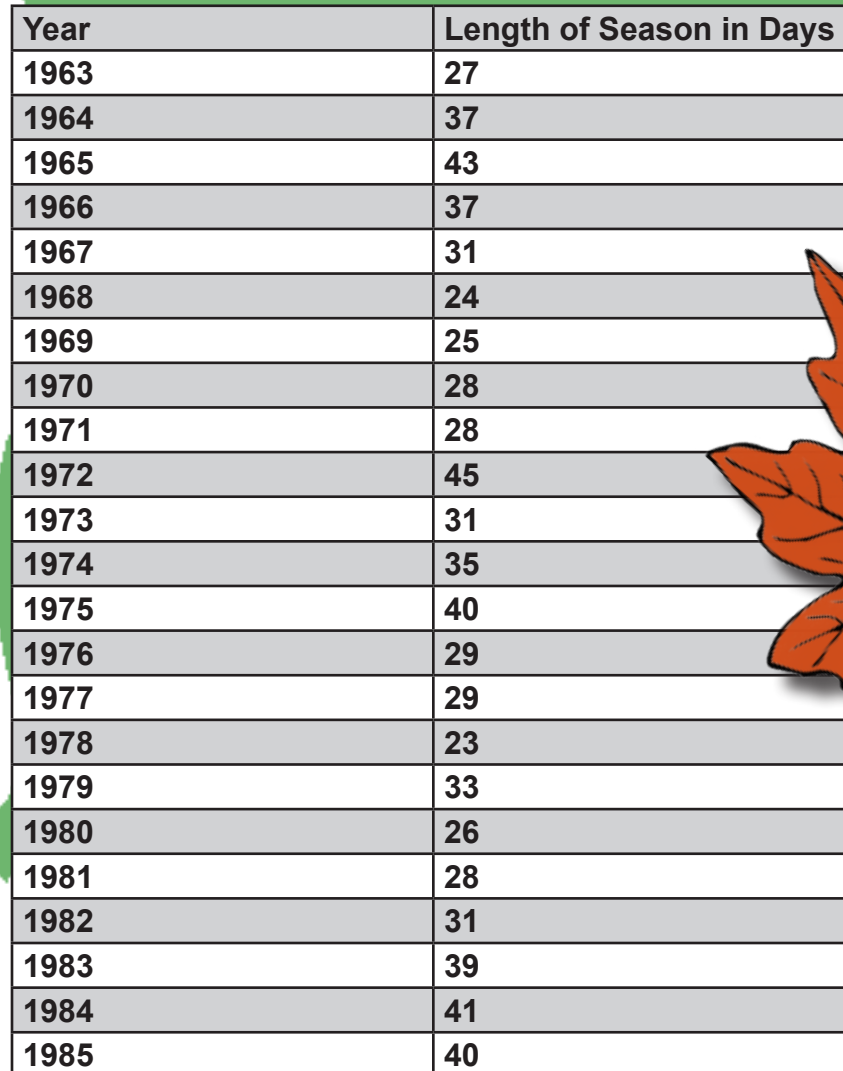


1963	19
1964	9.3
1965	4.3
1966	13
1967	12
1968	11
1969	19
1970	19.7
1971	17
1972	7
1973	4
1974	7
1975	6.7
1976	12.3
1977	16.5
1978	22
1979	13.5
1980	4.3
1981	9.3
1982	5
1983	9.3
1984	No data
1985	10
1986	No data

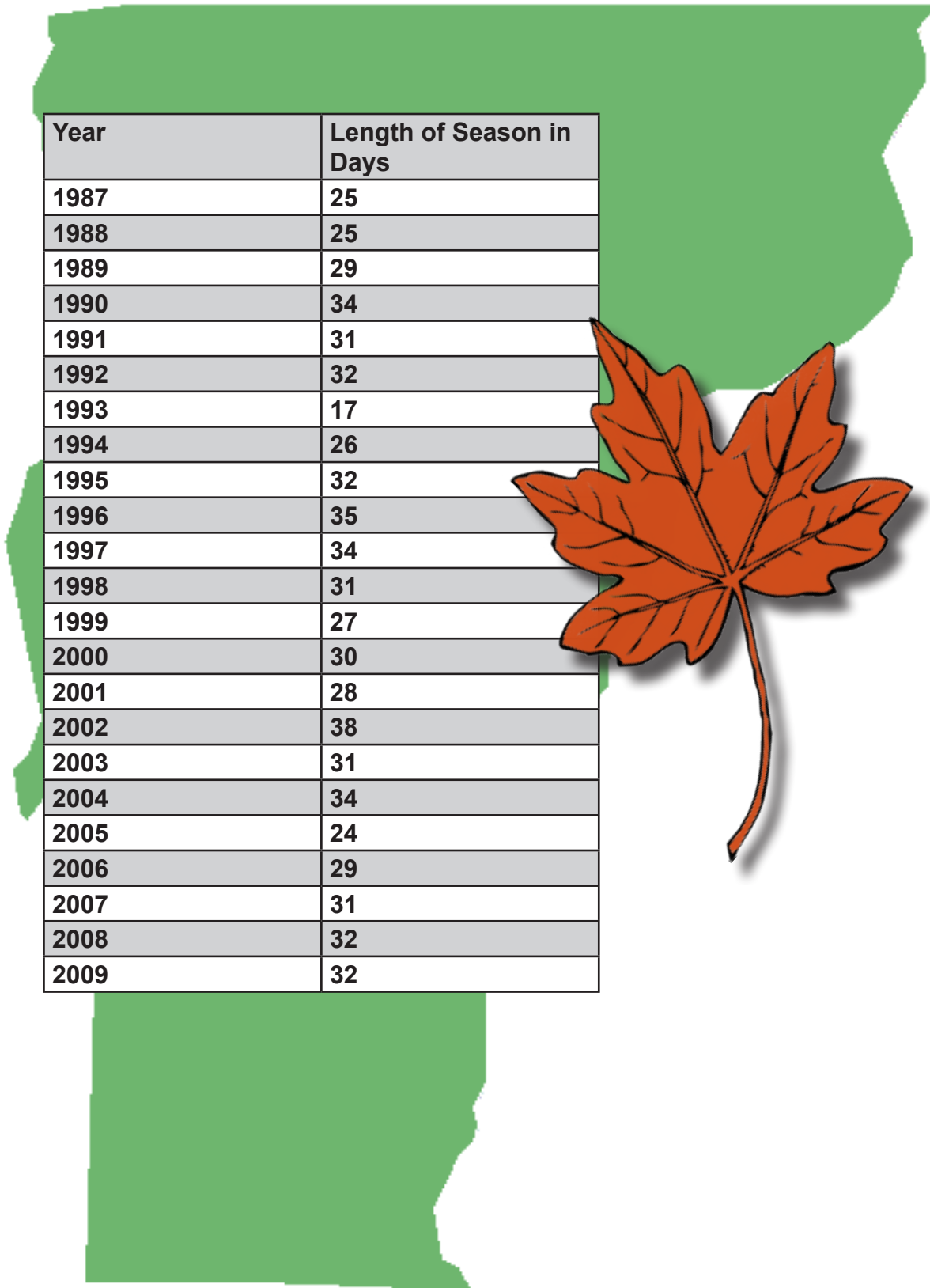
Data Set #4: Average Yearly Snow Depth in inches 1987-2009 for January, February, and March in Rutland, Vermont.¹⁰



1987	No data
1988	No data
1989	3.7
1990	6.7
1991	5
1992	4
1993	15
1994	27
1995	6.7
1996	12.7
1997	8.3
1998	7.3
1999	10
2000	9.7
2001	17.7
2002	4.7
2003	18.7
2004	8.7
2005	15
2006	5.7
2007	18.7
2008	10.7
2009	12

Data Set #5: Average Length of Sugaring Season in Vermont 1963-1986.²

Year	Length of Season in Days
1963	27
1964	37
1965	43
1966	37
1967	31
1968	24
1969	25
1970	28
1971	28
1972	45
1973	31
1974	35
1975	40
1976	29
1977	29
1978	23
1979	33
1980	26
1981	28
1982	31
1983	39
1984	41
1985	40

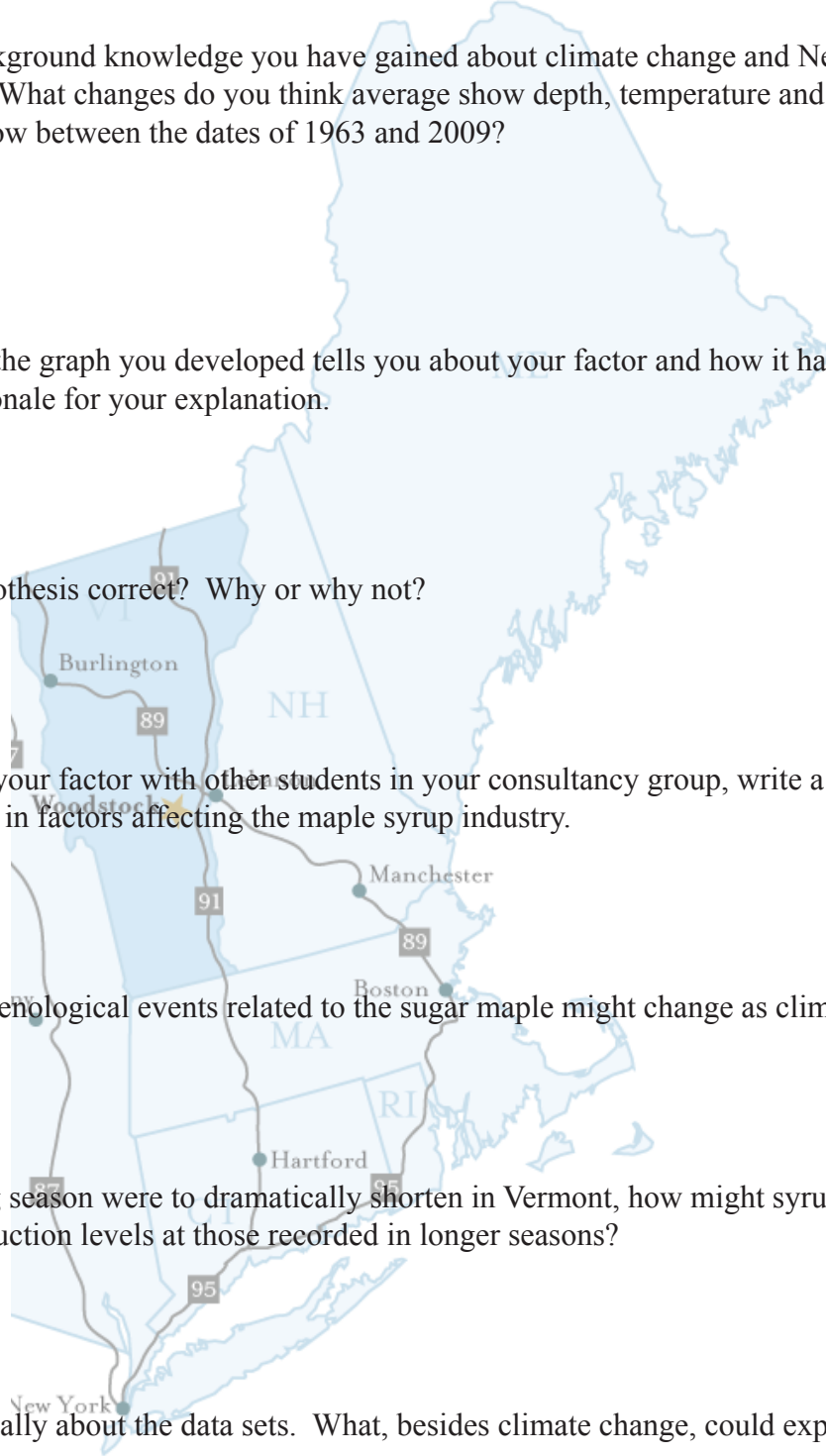
Data Set #6: Average Length of Sugaring Season in Vermont 1987-2009.²

Year	Length of Season in Days
1987	25
1988	25
1989	29
1990	34
1991	31
1992	32
1993	17
1994	26
1995	32
1996	35
1997	34
1998	31
1999	27
2000	30
2001	28
2002	38
2003	31
2004	34
2005	24
2006	29
2007	31
2008	32
2009	32

Exploration #3: Student Worksheet: Drawing Conclusions

Name: _____

1. Using the background knowledge you have gained about climate change and New England, develop a hypothesis. What changes do you think average snow depth, temperature and sugaring season length will show between the dates of 1963 and 2009?
2. Explain what the graph you developed tells you about your factor and how it has changed over time. Provide a rationale for your explanation.
3. Was your hypothesis correct? Why or why not?
4. After sharing your factor with other students in your consultancy group, write a summary statement about changes in factors affecting the maple syrup industry.
5. What other phenological events related to the sugar maple might change as climate changes?
6. If the sugaring season were to dramatically shorten in Vermont, how might syrup producers adapt to maintain production levels at those recorded in longer seasons?
7. Think analytically about the data sets. What, besides climate change, could explain the trends in the data?



Exploration #4:

Observing, Recording and Analyzing Phenological Events - Example Projects and Resources

Materials:

Vary depending upon project

Description:

The recording of phenological events can be done using many different species. The USA National Phenology Network (NPN) website has several presentations that walk citizen scientists through the steps of observation, recording, and reporting of data. Refer to the website to help develop a system that works for your classroom.

USA NPN website: http://www.usanpn.org/training_videos



Woodstock, VT during peak foliage. Ed Sharron photo

Example Project A: Establish a monitoring site for peak foliage. Consider a site that utilizes public lands like national parks, state parks, and state forests as well as school grounds. A simple platform and a digital camera can also be used to record observations at the whole-tree level. Set up a platform for a digital camera. A wooden stake with a flat platform screwed to the top will work fine. Set the platform at eye level for the average student. Place the digital camera to be used for monitoring on the platform and trace the base of the camera with a permanent marker so that any student placing a camera on the platform will capture the same image. Post all images for students to evaluate and determine a date for peak foliage. Any readily accessible and identifiable deciduous species may be used.

change process:

- o <http://www.vermontvacation.com/seasons/whychange.asp>
- o <http://www.maine.gov/doc/foliage/kids/movie.html>
- o <http://videos.howstuffworks.com/hsw/25263-evergreens-and-deciduous-why-leaves-change-color-video.htm>

Articles and videos that provide a brief overview of the color

Example Project B: Establish a monitoring program for comparison of tapped and untapped sugar maple trees. In order to complete a maple sugar monitoring project, a teacher must:

1. Locate a stand of sugar maple trees larger than 10 to 12 inches in diameter breast height.
2. Obtain permission to tap the trees.
3. Obtain materials to tap the tree, and tap once conditions are correct.
4. Develop a method for students to continually monitor the tap and sap flow.
5. Record all data and report to Journey North's Maple Sugaring Study.⁴
6. Continue to monitor phenological events in the tree stand, comparing the tapped and untapped trees.

Resource for tapping trees for maple syrup:

Heiligmann, Randall B., Melvin R. Koelling, and Timothy D. Perkins, eds. *North American Maple Syrup Producers Manual*. 2nd ed. Columbus: Ohio State University Extension, 2006. Print.

Example Project C: Phenological research using historical temperature and precipitation data (see link to the National Weather Service below).

Students can graph this information and determine if monthly temperatures have shifted in your area over the past 80-100 years. Then, have your students research:

1. The timing of an agricultural product for your state. For example, have students contact apple orchards to see if they have kept records on apple season dates to determine if temperature shifts have affected the length or timing of the season.
2. The arrival of a migrant bird in your state. For example, have students contact local conservation organizations, universities, and phenology websites (see links below) to determine if bird arrival has shifted along with the temperature shift.
3. Climate impacts in your area. Have students explore the potential effects of a climate change of a few degrees on the industries in your local area.

Example Project D: Bird Monitoring

Record the arrival of several bird species using eBird. Using the eBird website (<http://ebird.org/content/ebird>), students can submit their observations on bird arrival and view data submitted by other bird observers.

Additional Resources and Information:

- National Phenology Network (<http://www.usanpn.org/>)
- National Sustainable Agriculture Information Service (<http://www.attra.org/attra-pub/phenology.html>)
- USGS North American Bird Phenology Program (<http://www.pwrc.usgs.gov/bpp/>)
- Project Budburst (http://www.windows.ucar.edu/citizen_science/budburst/index.php)
- Project Budbreak (<http://budbreak.tc.cornell.edu/>)
- Journey North (<http://www.learner.org/jnorth/pde/PhenDataAbout.html>)
- Windows to the Universe (http://www.windows.ucar.edu/tour/link=/life/phenology_climate_change.html)
- National Weather Service (<http://www.nws.noaa.gov/>)



Black-throated Green Warbler
John Harrison photo

Resources and citations:

1. Belluck, Pam. "Warm Winters Upset Rhythms of Maple Sugar." Warm Winters Upset Rhythms of Maple Sugar. The New York Times, 3 Mar. 2007. Web. 15 Nov. 2009. <http://www.nytimes.com/2007/03/03/us/03maple.html?_r=1>.
2. Crop Production and Agricultural Review. New England Field Office, National Agricultural Statistics Service, U.S. Department of Agriculture, Concord, New Hampshire.
3. Frumhoff, P.C., J.J. McCarthy, J.M. Melillo, S.C. Moser, and D.J. Wuebbles. Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Synthesis report of the Northeast Climate Impacts Assessment (NECIA). Cambridge, MA: Union of Concerned Scientists (UCS). 2007.
1. "IPCC WG1 AR4 Report." IPCC AR4 WGI. Ed. S. Solomon, D. Qin, and M. Manning. Intergovernmental Panel on Climate Change. Web. 28 Nov. 2009. <<http://ipcc-wg1.ucar.edu/wg1/wg1-report.html>>.
1. "Journey North's Maple Sugaring Study." Signs of Spring: Maple Sugaring Study. Journey North. Web. 28 Nov. 2009. <<http://www.learner.org/jnorth/tm/spring/AboutSugar.html>>.
2. Keough, Gary R, Director. Maple Syrup 2009. Rep. Vol. June 12. Concord, NH: New England Agricultural Statistics, 2009. Print.
3. Lesley-Ann, Dupigny-Giroux. "Climate Variability and Socioeconomic Consequences of Vermont's Natural Hazards: A Historical Perspective." Vermont History 70.Winter/Spring (2002): 19-39. Print.
1. "Maple Facts : Proctor Maple Research Center : University of Vermont." The University of Vermont. Web. 15 Nov. 2009. <<http://www.uvm.edu/~pmrc/?Page=maplefacts.htm>>.
1. Morello, Lauren. "Climate Changing? Uncle Sam Wants Your Observations - NYTimes.com." Energy and Environment. New York Times, 23 June 2009. Web. 29 Nov. 2009. <<http://www.nytimes.com/cwire/2009/06/23/23climatewire-climate-changing-uncle-sam-wants-your-observ-64119.html>>.
1. "NOAA's National Weather Service - Rutland, VT - Monthly Average Snow Depth." National Weather Service Eastern Region Headquarters. NOAA. Web. 15 Nov. 2009. <http://www.erh.noaa.gov/btv/climo/BTV/monthly_totals/snowdepth.shtml>.
1. "NOAA's National Weather Service - Rutland, VT - Monthly Average Temperatures." National Weather Service Eastern Region Headquarters. NOAA. Web. 15 Nov. 2009. <http://www.erh.noaa.gov/btv/climo/BTV/monthly_totals/avgtemp.shtml>.
2. Sobel, David. Beyond Ecophobia: Reclaiming the Heart in Nature Education. Great Barrington, MA: Orion Society, 1996. Print.

Supplemental Articles

Accessible by following the links below or by downloading supplemental packet from Northeast Temperate Network website:

<http://science.nature.nps.gov/im/units/NETN/Education/Education.cfm#> and clicking on **Place Based Education Curriculum**

Introduction to Phenology:

http://northernwoodlands.org/outside_story/article/phenomenal_phenology/

Sugaring and Sugar Maples:

http://northernwoodlands.org/knots_and_bolts/sugar_content/

http://northernwoodlands.org/knots_and_bolts/red_versus_sugar/

http://northernwoodlands.org/discoveries/extra_calcium_boosts_maple_health/

http://northernwoodlands.org/articles/article/do_we_have_to_choose

<http://northernwoodlands.org/articles/article/anatomy-of-an-ice-damaged-sugar-maple/>

<http://www.usanpn.org/node/3514>

Climate Change:

http://northernwoodlands.org/outside_story/article/zoning_out_to_a_changing_climate/

http://northernwoodlands.org/articles/article/carbon_offsets_and_the_role_of_forests/

Color Change in Leaves:

http://northernwoodlands.org/articles/article/why_do_leaves_in_spring

