Climate Change in Vermont: Measuring Predicted Impacts

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Enduring Understanding:
Changes to the balance of Earth's systems can have widespread impacts that can be understood through the evaluation of empirical evidence and modeling.

Framework for K-12 Science Education Concepts:
ESS2D – Earth Systems – Weather and Climate

Essential Questions: 2-4
1. How can scientists distinguish the difference between normal fluctuations in weather patterns and the effects of climate change?
2. How do scientists predict the impacts of climate change?

Activity Introduction
In the *Emerging Science* episode "Climate Change: A Northeast Primer," students are introduced to present-day and potential future impacts of climate change on Vermont. Through these activities, students plan ways to measure climate change, explore climate change data, and use phenology to detect a species' response to climate change.

Pre-Viewing Activity

Think-Pair-Share
Think: Individually, students should write a response to the following prompt: "Vermont experienced extreme flooding due to Tropical Storm Irene in August of 2011. Do you think weather events like this will increase in frequency as a result of climate change?"
Pair: Students pair up and read their responses to each other. They take a couple of minutes to discuss their writing and extend their thoughts.
Share: Each pair shares one thought from their discussion with the whole class. Teacher facilitates a whole class discussion of the topic.

Post-Viewing Classroom Activities

Activity 1 - Measuring Climate Change: A Guided Brainstorming Activity

Through this guided brainstorm, students will imagine themselves and the climate of Vermont in the year 2065. In small groups, students will discuss and respond to the prompt below while taking notes to record their thinking. To conclude, students will share their responses with the whole class.

Prompt: It is the year 2065 in Vermont. Thinking back to the video about climate change that you watched back in 2013, you remember that scientists predicted an increase in the average annual temperature, an increase in average annual precipitation and an increase in the frequency of severe weather events over the next fifty years.

- Which of those events have become a reality? Describe how the climate has changed over the past fifty years as well as the impact on the Vermont environment, economy, human health, recreation, and food systems.
- What data would you use to show the change to Vermont's climate over the past fifty years? Imagine you have collected the data. Use the data to create a sketch of a graph showing the change.

Students are placed in groups of two or more. Groups are provided with the brainstorming prompts below. Groups work through the brainstorm, and record the results of their conversations. Finally, groups share their conversations with the whole class.

Activity 2: Climate Change and the Maple Syrup Industry in Vermont - Data Exploration

Materials needed:
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
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.nsrfharmony.org/protocol/doc/text_rendering.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

❑▪ Article #2: "Warm Winters Upset Rhythms of Maple Sugar"
http://www.nytimes.com/2007/03/03/us/03maple.html?_r=3&oref=slogin&

Primary Research Documents:
❑▪ Article #3: Duchesne, L., Houle, D., Cote, M.A., Logan, T, 2009. Maple Sugaring by Red Squirrels. Forest Ecology and Management. 258, 2683-2689.

❑▪ Article #4: Heinrich, B, 1992. Modeling the effect of climate on maple syrup production in Quebec, Canada. 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 two sets for each of the following factors: average temperature, average snow depth, and average season length. Using the student 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 two data sets 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. Ask questions like: Is this a significant difference? What is this graph telling you? If there is a teacher of statistics at your school, that person will be an excellent resource for the analysis of the graphs.
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.

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

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

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Data Set #2: Average Temperature in degrees Fahrenheit 1987-2009 for the months of January, February, March and April in Rutland, Vermont[1]

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[2]

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[2]

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[3]

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
1986	25

_Data Set #6: Average Length of Sugaring Season in Vermont 1987-2009[3]

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

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Activity #2: Climate Change and Maple Syrup Production in Vermont
Student Worksheet
Data Analysis Questions

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?

Activity 3: Measuring the Impact of Climate Change with Phenology

One of the ways scientists determine the impact of climate change is through monitoring the cycles of living organisms, a branch of science called phenology. 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 (Find the USA NPN website in the resource section). An introductory discussion activity as well as three example projects for phenological monitoring are below:

Introduction to Phenology: A Discussion

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.

3. Show students websites for recording and posting observations about phenological events such as:

USA National Phenology Network's Natures Notebook:
http://www.usanpn.org/user?destination=MyNPN
*Note: You must first login and create an account to use this site.
Project Budbreak: http://budbreak.tc.cornell.edu/
Project BudBurst: http://www.windows.ucar.edu/citizen_science/budburst/
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:

How might scientists use data collected over a number of years?
What would happen if the first frost came earlier or later than usual?
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?

7. Relate discussion of phenological events and monitoring to climate change. Discuss the importance of recording and reporting phenological events as the climate changes.

Example Project 1: Peak Foliage

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 be used to record observations at the whole-tree level. 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. (See "Keeping a Digital Eye on Nature's Clock" in resource section for an excellent article on this project).

Example Project 2*:* Maple Sap Production

In order to complete a maple sugar monitoring project, a teacher must locate a stand of sugar maple trees larger than 10 to 12 inches in diameter breast height, tap the trees, and develop a method for students to continually monitor the tap and sap flow. Students record all data and report to Journey North's Maple Sugaring Study (see resource section). Students can continue to monitor phenological events in the tree stand, comparing the tapped and untapped trees over time. (See resource section for a guide to tapping sugar maple trees)

Example Project 3: Bird Monitoring

Record the arrival of several bird species using eBird. Using the eBird website (see resource section), students can submit their observations on bird arrival and view data submitted by other bird observers.

Additional Resources

eBird: (http://ebird.org/content/ebird/)

Journey North's Maple Sugaring Study:
(http://www.learner.org/jnorth/tm/spring/AboutSugar.html)

Magney, Troy, Karla Eitel, Jan Eitel, Vincent Jansen, Jenny Schon, Rebecca Rittenburg, and Lee Vierling. "Keeping A Digital Eye on Nature's Clock: Students Use Digital Cameras to Monitor Plant Phenology." *The Science Teacher* 80.1 (2013): 37-43. Web.

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.

Project BudBreak: (http://budbreak.org)

Project BudBurst: (http://neoninc.org/budburst/)

USA National Phenology Network: (www.usanpn.org)

USGS North American Bird Phenology Program: (http://www.pwrc.usgs.gov/bpp/)

Works Cited

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. "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>.

3. *Crop Production* and *Agricultural Review.* New England Field Office, National Agricultural Statistics Service, U.S. Department of Agriculture, Concord, New Hampshire.