School of ICE

Decoding Ice Cores

Atmospheric Analysis

How much carbon dioxide was in the atmosphere in Earth's past?

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Student Directions-Decoding Ice Cores

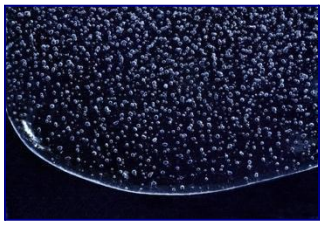
How much CO_2 was in the atmosphere in the past?



Ice cores provide climate scientists with evidence of past CO_2 levels. Climate scientists can directly measure past atmospheric gases by analyzing the air bubbles trapped in ancient ice. Ice cores are retrieved by drilling through glaciers. A small part of the core is melted to release the gases from the trapped bubbles. The amount of CO_2 and other gases is then measured directly using a mass spectrometer.

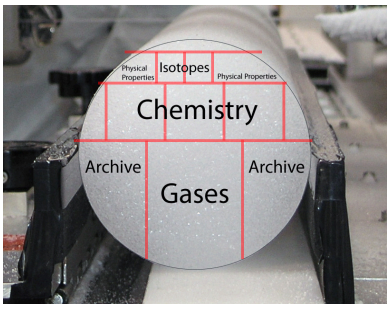


In the laboratory, an ice core sample melts under vacuum to release the ancient air bubbles for analysis. Photo: Anais Orsi



Ancient air bubbles visible in a thin slice of an ice core.

In this lab, the relative amount of CO_2 in melted ice core samples will be determined using a conductivity meter instead of a mass spectrometer. When carbon dioxide is dissolved in water it forms carbonic acid. Carbonic acid makes the water a better conductor of electricity.



- Samples without much carbon dioxide dissolved should have lower conductivities.
- Samples with higher amounts of carbon dioxide dissolved should have higher conductivities.

The relative amount of CO_2 in melted samples of “ice cores” will be analyzed from ice that formed at different times in the past. The youngest sample will represent ice being formed today, the oldest sample will represent ice that formed almost a half a million years ago.

Pre-Investigation Questions

1. What do you think the dependent variable is in this investigation?
2. What do you think the independent variable is in this investigation?
3. What do you predict the evidence will reveal about the amount of carbon dioxide in the Earth’s atmosphere over the past 500,000 years?

Student Directions-Decoding Ice Cores

How much CO_2 was in the atmosphere in the past?



Procedure:

Directions for using the TDS meter:



1.Turn on the meter.

- Press “Shift” until conductivity units of microsiemens/cm (µS/cm) is displayed.

2.Insert the meter into each water sample.

- On the "Ice Core Sample Data Table" **record each reading after about five seconds.**

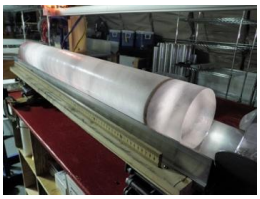
Directions for Data Collection:

Each ice core is represented by a plastic cup containing water. The water represents the melted ice core sample. At each station…

1. Record the age of the sample.
2. Rinse the conductivity meter in distilled water then use the clean TDS meter to measure the conductivity of the melted ice core sample. **(Record after ~ 5 seconds.)**
3. Continue until you have data on all 11 cores.
4. Compare your data with other groups to reach a consensus value for the conductivity.

Student Directions-Decoding Ice Cores

How much CO_2 was in the atmosphere in the past?



Ice Core Data Table

Lab Partner Names:

_____

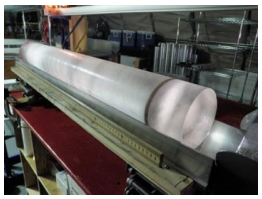
_____

Evidence:

Ice Core #	Age of the ice. (*Enter years before present as negative numbers.*)	Measured Conductivity (µS/cm)	Group #2 Measured Conductivity (µS/cm)	Group #3 Measured Conductivity (µS/cm)	Final Consensus Agreed Upon Measurement (µS/cm)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					

Student Directions-Decoding Ice Cores

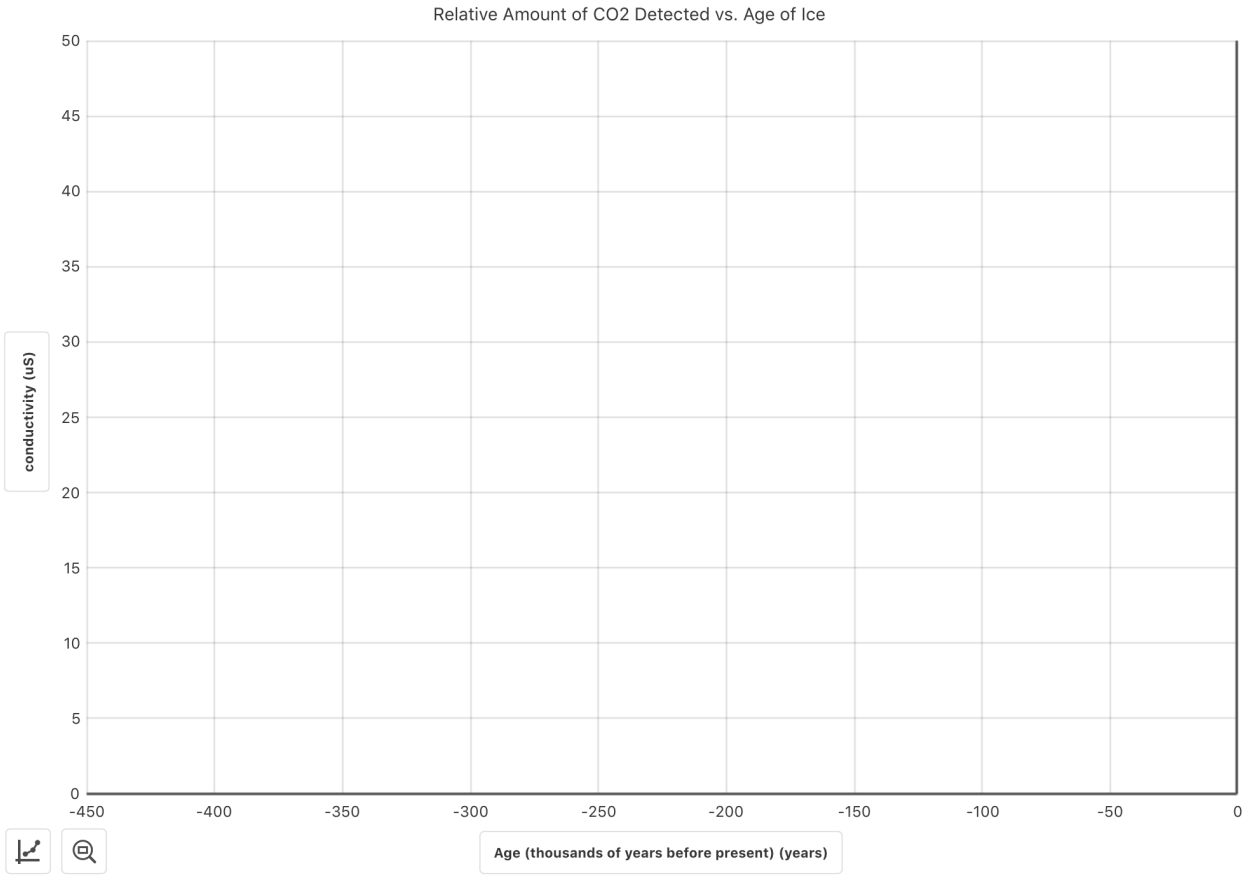
How much CO_2 was in the atmosphere in the past?



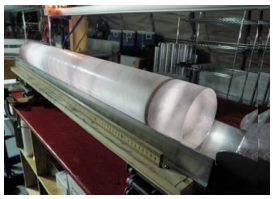
Graphing Your Data

Directions:

1. Make an X-Y scatter graph of "Amount of CO_2 vs. Age of Ice".
2. Connect the data points with lines that show how the amount of CO_2 most likely changed between the samples analyzed.
3. Label the data points with the highest CO_2 levels as "warm climates"; Label the data points with lowest CO_2 levels as "cold climates".



Student Directions-Decoding Ice Cores
How much CO_2 was in the atmosphere in the past?



Analysis Questions:

1. What are two different things the data collected in this lab suggest about the amount of CO_2 in the atmosphere during the past 500,000 years? Support your claims with evidence.
2. What is one way the model for determining CO_2 in this lab is similar to what real scientists do when analyzing real ice cores?
3. What is one way the model for determining CO_2 in this lab is different from what real scientists do when analyzing real ice cores?
4. Make two claims about trends that you see in the data. Support each claim with evidence from the lab.
5. Recently, scientists have published findings from the WAIS Divide (West Antarctic Ice Sheet) ice core project in Antarctica. This ice core contains data that suggests abrupt climate changes have occurred in as little as 10 years. What is the shortest change in climate observed in the data collected in this lab?

3-2-1 Inquiry Questions

Three things I noticed about the data in the graph are…

1.

2.

3.

Two things I wonder about based on the data collected in this lab are…

1.

2.

The one most important thing I think the data suggest is…

1.

Teacher Resources-Decoding Ice Cores

How much CO_2 was in the atmosphere in the past?

Preview

Students will investigate how the amount of CO_2 has changed in the atmosphere over the past 500,000 years. Students will use a conductivity meter to determine the amount of carbon dioxide (CO_2) in a model of a melted ice core sample. After taking their measurements, they will graph their results and then compare their data with that of the actual 800,000 year ice core record.

Resources Included

- **Background for the teacher**
- **Key concepts**
- **Model analysis**
- **Directions for set up**
- **Answer keys, sample data, sample graphs**
- **NGSS connections**
- **Additional resources**

Materials

1 TDS Meter/ group
available on Amazon:
https://www.amazon.com/gp/product/B01FPG89CE/ref=ppx_yo_dt_b_asin_title_o08_s00?ie=UTF8&psc=1

Or…
Vernier conductivity probe.
Vernier part #CON-BTA

11 plastic cups

11 cups of distilled or deionized water (1 at each station) for rinsing TDS meter between tests

Sparkling water (not spring water) (OR Soda Stream)

Deionized or distilled water

Copy of the "Ice Core Data Table" and the "Graph" page

Or…
Computer graphing using Vernier Graphical Analysis

Teacher Resources-Decoding Ice Cores

How much CO_2 was in the atmosphere in the past?

Background for the Teacher

Ice cores provide climate scientists with direct evidence of past CO_2 levels through measurements taken from air bubbles trapped in ancient ice. Climate scientists can also determine the temperature of the Earth when the snow that formed the ice fell by using proxy measurements of hydrogen and/or oxygen isotopes in the ice. (See Ice Core Lab #3 for a lab activity related to determining historical temperatures.)

Real climate scientists determine the amount of CO_2 in ice cores by melting a small sample from the ice core, then analyzing the gases released from the trapped air bubbles using a mass spectrometer. In this lab, the relative amount of CO_2 in each sample will be determined using a conductivity meter instead of a mass spectrometer.

When carbon dioxide is dissolved in water it forms carbonic acid. Carbonic acid makes the water a better conductor of electricity. Samples without much carbon dioxide dissolved should have lower conductivities. Samples with higher amounts of carbon dioxide dissolved should have higher conductivities. This lab we will measure the relative amount of CO_2 in melted samples of ice cores from different times in the past. The youngest sample will represent ice being formed today, the oldest sample will represent ice that formed almost a half a million years ago.

Teacher Resources-Decoding Ice Cores

How much CO_2 was in the atmosphere in the past?

Key Concepts

1. Identifying independent and dependent variables
2. Evidence from ice cores indicate that CO_2 in the atmosphere has ranged from about 180 ppm during ice ages to about 280 ppm during interglacial periods.
3. When discussing the ice core records of CO_2, students should see that today's measurements of CO_2 are way above the natural cycles of the past 800,000 years.
4. In natural cycles, CO_2 has changed over predictable time periods of about 20,000, 40,000 and 100,000-year cycles. These are known as the Milankovitch Cycles which are based on the shape of Earth's orbit (eccentricity), the tilt of its axis (axial precession) and its rotational tilt (obliquity). In this lab, students don't need to understand these cycles, but should see in their graphs that there are regular cycles of climate change.
5. Students should notice that the **rate** of change is much faster today than in the natural cycles. This should be obvious from the data taken from 1850 to the present.
6. Evidence from Greenland ice cores (NGRIP, GRIP and GISP2) show that abrupt climate change can happen in as little as 10 years. To obtain this evidence scientists have analyzed many more samples than analyzed in this lab. The abrupt changes show up with these higher resolution analytical methods.

Teacher Resources-Decoding Ice Cores

How much CO_2 was in the atmosphere in the past?

Model Analysis

Activity-Lab-2:
Decoding Ice Cores: How much CO2 was in the atmosphere in the past?

Comparing the relative amount of carbon dioxide present in ice core samples from the past 500,000 years.

NGSS Connection: Some systems can only be studied indirectly because they are too small or too large to observe directly.

Classroom Model	Learning Goal	Real Ice Core Data
The classroom model measured the relative amounts of CO_2 in samples of "melted ice cores" using conductivity meters. Conductivity meters are used to determine the relative levels of carbon dioxide present by differences in conductivity measured in units of **µS/cm (microsiemens/cm)**. The conductivity differences result from increased levels of carbon dioxide that forms carbonic acid.	Scientists can reconstruct the composition of the atmosphere in the past by using instruments that gather evidence from gases trapped in bubbles of ancient ice recovered from ice cores. Instruments allow for a comparison of the relative amounts of gases present.	Scientists analyze gases released from trapped air bubbles released when samples of the ice core are melted. Mass spectrometers are used to determine the relative levels of carbon dioxide expressed in ppm.

Teacher Resources-Decoding Ice Cores

How much CO_2 was in the atmosphere in the past?

Setting up the ice core test samples:



1. Get 11 plastic cups to represent 11 sections of the ice core. Number the cores 1-11 and record the relative age on the cup (see data table below). Fill each cup with the approximate levels of sparkling/carbonated water, and deionized/distilled water given in the table below.



2. Once set up, the amount of CO_2 dissolved in the water will begin to decrease; however; even after a few hours significant differences will still be measurable. If you are going to do the lab all day long, you may want to set up fresh samples at lunch.

HINTS: Be careful what type of sparkling water you purchase. Some spring water like Perrier has so many dissolved minerals that the conductivity measured is mainly due to the minerals dissolved in the water. You can generate your own carbonated water using deionized water and a Soda Stream. (Data from a Soda Stream experiment are below.) Another option is to choose a sparkling spring water that has fewer dissolved minerals such as the Crystal Geyser.

Correction factors. You can modify the lab to subtract out the conductivity due to the dissolved minerals. Sample data is provided in the table that will allow you to determine the correction factor needed for your sparkling water. For example, refer to sample core #1 in the table below. The carbonated distilled water had a conductivity of 44 uS/cm. The sparkling water had a conductivity of 175 uS/cm. Using this sparkling water the correction formula would be based on the difference between these conductivities. (175uS/cm - 44 uS/cm = 131 uS/cm)

Sparkling Water Conductivity - 131 uS/cm = Conductivity due only to CO_2

Teacher Resources-Decoding Ice Cores

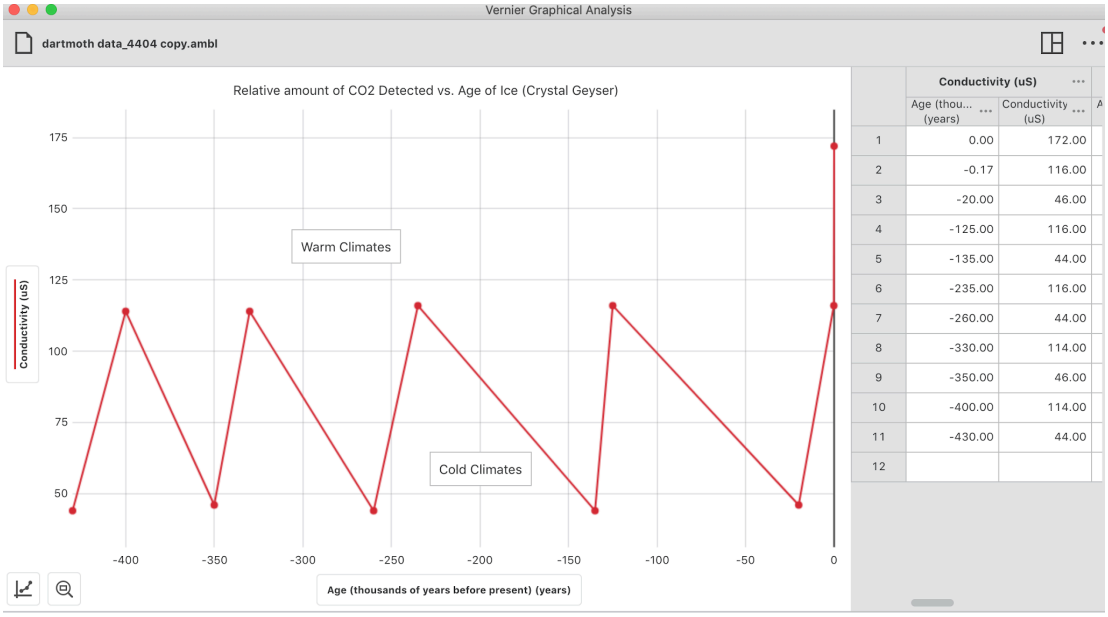
How much CO_2 was in the atmosphere in the past?

Set-up Directions			Sample Data	
Ice Core #	**Core Age (Negative numbers represent years before present time)**	**Carbonated Water Mixing Instructions**	**Sample data using distilled water and carbonated distilled water (μS/cm)**	**Sample data using Crystal Geyser Sparkling Spring Water**
1	Present Time 0	100% Carbonated	44	175
2	-170 (~1850 pre-industrial revolution)	~50% distilled and ~50% carbonated	35	100
3	-20,000	~90% distilled + ~10% carbonated	20	24
4	-125,000	~50% distilled and ~50% carbonated	36	102
5	-135,000	~90% distilled + ~10% carbonated	18	22
6	-235,000	~50% distilled and ~50% carbonated	36	112
7	-260,000	~90% distilled + ~10% carbonated	10	20
8	-330,000	~50% distilled and ~50% carbonated	32	116
9	-350,000	~90% distilled + ~10% carbonated	15	30
10	-400,000	~50% distilled and ~50% carbonated	40	110
11	-430,000	~90% distilled + ~10% carbonated	10	25

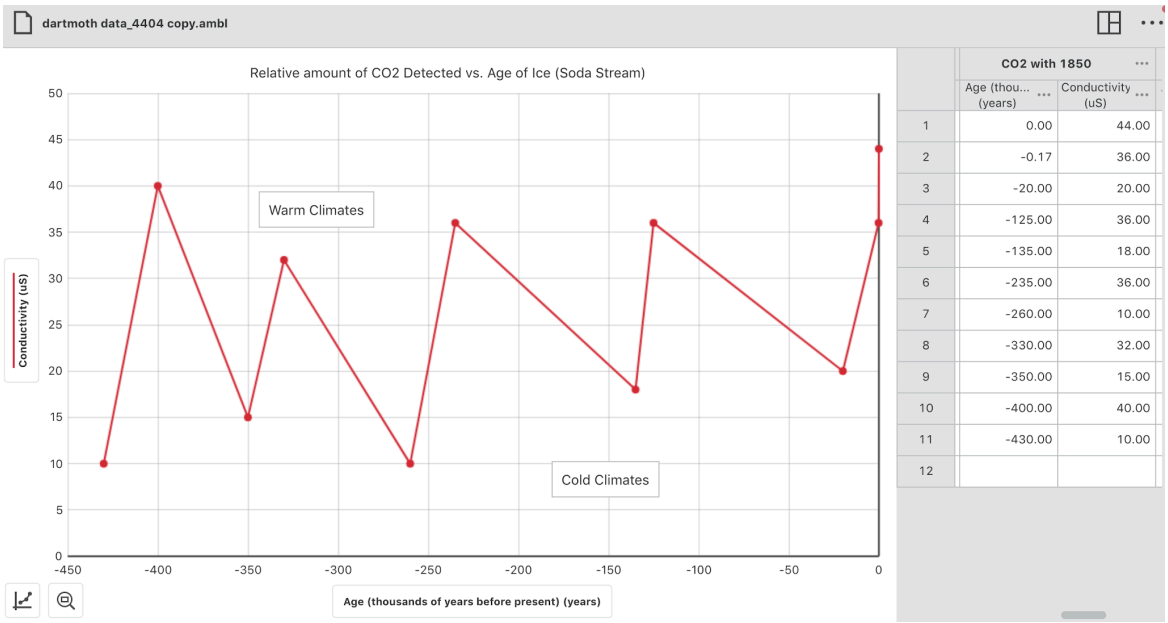
Teacher Resources-Decoding Ice Cores

How much CO_2 was in the atmosphere in the past?

Sample Graphs using Distilled water and a Crystal Geyser Sparkling Spring Water (top) and Soda Stream (bottom).



	Conductivity (uS)	
	Age (thou... (years)	Conductivity (uS)
1	0.00	172.00
2	-0.17	116.00
3	-20.00	46.00
4	-125.00	116.00
5	-135.00	44.00
6	-235.00	116.00
7	-260.00	44.00
8	-330.00	114.00
9	-350.00	46.00
10	-400.00	114.00
11	-430.00	44.00
12		



	CO2 with 1850	
	Age (thou... (years)	Conductivity (uS)
1	0.00	44.00
2	-0.17	36.00
3	-20.00	20.00
4	-125.00	36.00
5	-135.00	18.00
6	-235.00	36.00
7	-260.00	10.00
8	-330.00	32.00
9	-350.00	15.00
10	-400.00	40.00
11	-430.00	10.00
12		

Teacher Resources-Decoding Ice Cores
How much CO_2 was in the atmosphere in the past?

Possible Answers to Questions:

Pre-Investigation Questions

1. What do you think the dependent variable is in this investigation?
   - The dependent (responding) variable could be identified as either the conductivity or the relative amount of CO_2.

2. What do you think the independent variable is in this investigation?
   - The independent variable is the age of the melted ice sample.

3. What do you predict the evidence will reveal about the amount of carbon dioxide in the Earth's atmosphere over the past 500,000 years?
   - Student predictions will vary but it is important to pull out their prior knowledge and background knowledge prior to starting the lab.

Analysis Questions:

1. What are two different things that the data collected in this lab suggest about the amount of CO_2 in the atmosphere during the past 500,000 years? Support your claims with evidence.
   - *The data suggest that the climate tends to bounce between ice ages and warmer periods. Evidence to support this from the graph is that there appear to be five times in the past 450,000 years when the Earth was in an ice age, and five times when the climate was warm like today.*
   - *The data suggest that the climate warms up faster than it cools off during the ice-age/warm period cycle. Evidence to support this is that the interval between warm and cold is about 100,000 years, and the time interval between cold and warm is only about 25,000 years.*

2. What is one way the model for determining CO_2 in this lab is similar to what real scientists do when analyzing real ice cores?
   - Real scientists melt the ice cores and test the liquid water samples to measure the amount of CO_2 released from the bubbles in the ice.
   - This lab also measured the amount of CO_2 present in liquid water.

Teacher Resources-Decoding Ice Cores
How much CO_2 was in the atmosphere in the past?

Possible Answers to Questions cont…

Analysis Questions cont...

3. What is one way the model for determining CO_2 in this lab is different from what real scientists do when analyzing real ice cores.
    - Real scientists use mass spectrometers to measure the amount of CO_2. This lab used conductivity meters to measure the amount of carbonic acid present from the dissolved CO_2.

4. Make two claims about trends that you see in the data. Support each claim with evidence from the lab.
    - Answers will vary. Encourage students to respond to this question with the sentence starter of "The data suggest…. Evidence to support this is…" For example: *The data suggest that carbon dioxide levels now are outside the range that they have been in for the past 500,000 years. Evidence to support this is that before 1850 conductivity/CO_2 levels went between 55 uS/cm and 120 uS/cm and now the present sample is about 170 uS/cm.*

5. Recently, scientists have found data from the WAIS Divide ice core in Antarctica that suggests abrupt climate changes have occurred in as little as 10 years. What is the shortest change in climate seen in the data from this lab?
    - Answers will vary. Encourage students to respond to this question with the sentence starter of "The data suggest…. Evidence to support this is…" For example: *The data suggest that the shortest time for the climate to change historically has been approximately 10,000 years. Evidence to support this is that 135,000 years ago the conductivity/CO_2 level was 18uS/cm and 125,000 years ago the conductivity/CO_2 level went up to 36 uS/cm.*

Teacher Resources-Decoding Ice Cores

How much CO_2 was in the atmosphere in the past?

Next Generation Science Standards (NGSS)

Science and Engineering Practices

1. **Asking Questions and Defining Problems.** Students at any grade level should be able to ask questions of each other about the features of the phenomena they observe and the conclusions they draw from their scientific investigations. (NRC Framework 2012, p. 56)
2. **Planning and Carrying Out Investigations.** Students should have opportunities to plan and carry out several different kinds of investigations during their K-12 years. (NRC Framework, 2012, p. 61)
3. **Analyzing and Interpreting Data.** Once collected, data must be presented in a form that can reveal any patterns and relationships and that allows results to be communicated to others. (NRC Framework, 2012, p. 61-62)
4. **Engaging in Argument from Evidence.** Students should argue for the explanations they construct and defend their interpretations of the associated data. (NRC Framework, 2012, p. 73)

Cross Cutting Concepts

1. **Patterns.** Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
2. **Cause and Effect: Mechanism and Explanation.** Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated.
3. **Scale, Proportion, and Quantity.** In considering phenomena, it is critical to recognize what is relevant at different measures of size and time.
4. **Systems and System Models.** Defining the system under study—specifying its boundaries and making explicit a model of that system.
5. **Energy and Matter: Flows, Cycles, and Conservation.** Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
6. **Stability and Change.** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

Next Generation Science Standards (NGSS) cont...

Disciplinary Core Ideas

ESS2A Earth Materials and Systems

- 6-8. Energy flows and matter cycles within and among Earth's systems, including the sun and Earth's interior as primary energy sources.
- 9-12. Feedback effects exist within and among Earth's systems.

ESS3C Human Impacts on Earth Systems

- 6-8. Human activities have altered the biosphere, sometimes damaging it, although changes to environments can have different impacts for different living things. Activities and technologies can be engineered to reduce people's impacts on Earth.
- 9-12. Sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources, including the development of technologies.

ESS3D Global Climate Change

- 3-5. If Earth's global mean temperature continues to rise, the lives of humans and other organisms will be affected in many different ways.
- 6-8. Human activities affect global warming. Decisions to reduce the impact of global warming depend on understanding climate science, engineering capabilities, and social dynamics.
- 9-12. Global climate models used to predict changes continue to be improved, although discoveries about the global climate system are ongoing and continually needed.

Additional Resources

WAIS Divide: http://www.waisdivide.unh.edu/

Labels for CO_2 Cups

Ice Core #1 **Age of Ice** **0 years (Present)** *(CO_2)*	**Ice Core #2** **Age of Ice** **-170 years (~1850)** *(CO_2)*	**Ice Core #3** **Age of Ice** **-20,000 years** *(CO_2)*
Ice Core #4 **Age of Ice** **-125,000 years** *(CO_2)*	**Ice Core #5** **Age of Ice** **-135,000 years** *(CO_2)*	**Ice Core #6** **Age of Ice** **-235,000 years** *(CO_2)*
Ice Core #7 **Age of Ice** **-260,000 years** *(CO_2)*	**Ice Core #8** **Age of Ice** **-330,000 years** *(CO_2)*	**Ice Core #9** **Age of Ice** **-350,000 years** *(CO_2)*
Ice Core #10 **Age of Ice** **-400,000 years** *(CO_2)*	**Ice Core #11** **Age of Ice** **-430,000 years** *(CO_2)*	**Lab #2 Labels** **CO_2 Levels**