The Exploratorium Teacher Institute and Institute for Inquiry Present

NGSS STEM Conference 2020

All Systems Go!

Investigating Earth Systems Science in All Science Classrooms

Changing the Carbon Cycle

Carbon cycles between living things and nonliving things. Using NOAA atmospheric carbon dioxide data as an anchor phenomenon, we'll explore our changing atmosphere and its effect on the carbon cycle. What signals in the data can be attributed to cyclical interactions between living and nonliving systems? What signals can be attributed to human impacts? Additionally, we'll use a sequencing tool developed by the Teacher Institute to develop an NGSS-aligned instructional unit for this topic.

Presented by Lori Lambertson, Exploratorium Teacher Institute
This page and all these links can be found at: ***https://tinyurl.com/NGSS-carbon-cycle***

Our Changing Atmosphere
Graph NOAA data to tell a story about our changing atmosphere. What do you notice? What do you wonder? Record what students notice and wonder about their graphs. Put the graphs together in chronological order. Ask again: What do you notice? What do you wonder? These "noticings" and "wonderings" provide a rich array of authentic options to explore.

Making Phenomena Local
NOAA ESRL's Interactive Data Viewer Select any station to see the atmospheric carbon dioxide data in graphic form.

Follow the Carbon
Use rice to model the reservoirs and fluxes of carbon in the global carbon cycle. This "Science Snack" models the carbon cycle, the interactions between the atmosphere, ocean and terrestrial biosphere (plants and soils), and the addition of carbon dioxide from fossil fuels.

Ocean Acidification in a Cup

How can a change in the atmosphere change the ocean below? Observe what happens to the "ocean" when we add additional carbon dioxide to the atmosphere above it.

Related Exhibits:
Carbon Dioxide Buoy (in the water between Piers 15 and 17)
Carbon Dioxide Buoy Data Screen (Gallery 6, Observatory)
Hot Pile (Gallery 4)
Additional Resources
Changing the Carbon Cycle google slide show
Daily Global Trend, with data from Barrow, Mauna Loa, South Pole and American Samoa.
Carbon Dioxide Movie, animation shows carbon dioxide levels for the past 800,000 years.
Creating Activity Sequences for NGSS from the Exploratorium

User Friendly Mauna Loa Atmospheric CO_2 Data, full Keeling Curve Data
Mauna Loa Average Monthly Atmospheric CO_2 data in ppm, 1958-2019 (NOAA)
Primary Source for Mauna Loa Atmospheric CO_2 Keeling Curve Data
NOAA's Earth System Research Lab

NGSS Connections to Disciplinary Core Ideas (MS and HS DCIs)
Our Changing Atmosphere will engage learners in the science practices associated with analyzing and interpreting data, making observations and asking questions, and engaging in mathematical thinking by looking for patterns and making predictions.
In addition to patterns, further discussions about the data may reveal the cross cutting concepts of cause and effect (why is this happening?), stability and change (was it always like this?), and the cycling of matter (where is the carbon dioxide coming from?).

1) Human Impacts on Earth Systems, MS ESS3.C Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Performance Expectations include MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

2) Climate Change, MS-ESS3.D
Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

Performance Expectations include MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

3) Climate Change, HS-ESS3.D Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.

Performance Expectations include HS-ESS3-6 Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Follow the Carbon will engage learners in the science practice of developing and using a model to understand the carbon cycle. This Snack also addresses the cross cutting concepts associated with energy and matter: flows, cycles and conservation of matter. Further discussions can include a comparison of the cycling of carbon through the fast carbon cycle versus the slow carbon cycle, and about the different states and forms carbon takes as it cycles through the earth's systems.

1) Earth Materials and Systems, MS-ESS2.A The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

Performance Expectations include MS-ESS2-2 Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

2) Earth Materials and Systems, MS-ESS2-1. Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.

Performance Expectations include MS-ESS2.A All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.

3) Human Impacts on Earth Systems, MS-ESS3.C Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Performance Expectations include MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

4) Weather and Climate, HS-ESS2.D Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.

Performance Expectations include HS-ESS2-6 Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

5) Climate Change, HS-ESS3.D Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.

Performance Expectations include HS-ESS3-6 Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Ocean Acidification in a Cup will engage learners in the science practice of developing and using a model to understand how the ocean is changing. Furthermore, experimental results of this Snack provide opportunities for students to construct explanations based on their evidence. This Snack also addresses the cross cutting concept of cause and effect, as a change in the "atmosphere" causes a change in the "ocean" below it.

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Environmental Principles and Concepts

Principle 2 - People Influence Natural Systems
The long-term functioning and health of terrestrial, freshwater, coastal, and marine ecosystems are influenced by their relationships with human societies.
Concept A. Direct and indirect changes to natural systems due to the growth of human populations and their consumption rates influence the geographic extent, composition, biological diversity, and viability of natural systems.

Principle 3 - Natural Systems Change in Ways that People Benefit From and Influence
Natural systems proceed through cycles that humans depend upon, benefit from, and can alter.
Concept A. Natural systems proceed through cycles and processes that are required for their functioning.
Concept C. Human practices can alter the cycles and processes that operate within natural systems.

Principle 4 - There are no Permanent or Impermeable Boundaries that Prevent Matter from Flowing Between Systems
The exchange of matter between natural systems and human societies affects the long-term

functioning of both.
Concept B. The byproducts of human activity are not readily prevented from entering natural systems and may be beneficial, neutral, or detrimental in their effect.
Concept C. The capacity of natural systems to adjust to human-caused alterations depends on the nature of the system as well as the scope, scale, and duration of the activity and the nature of its byproducts.