STRATFORD PUBLIC SCHOOLS
Stratford, Connecticut

"Tantum eruditi sunt liberi"
Only The Educated Are Free

Earth & Energy Systems

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DISTRICT MISSION STATEMENT

The mission of the Stratford school community is to ensure that all students acquire the knowledge, character, and 21st century skills to succeed through high quality learning experiences and community partnerships within a culture of diversity and respect.

Portrait of a Stratford Graduate

- Responsible and Involved Citizen
  - Participate in and contribute with empathy and respect to the community.
  - Demonstrate knowledge of and respect for diverse cultures, identities, and perspectives.
  - Practice responsible digital and in person citizenship as a member of a community.

- Creative and Practical Problem-Solver
  - Define and analyze a problem/problems.
  - Select, evaluate, and apply appropriate resources/strategies necessary to find/generate a solution(s) for problems.
  - Generate and critically evaluate the effectiveness of a solution.

- Informed and Integrative Thinker
  - Apply knowledge from various disciplines and contexts to real life situations.
  - Analyze, evaluate, and synthesize information from multiple and diverse sources to build on and utilize knowledge.
  - Use evidence and reasoning to justify claims/solutions.

- Clear and Effective Communicator
  - Select and use communication strategies (questioning, clarifying, verifying, and challenging ideas) and interpersonal skills to collaborate with others (peers, teachers, community members, families) within a diverse community.
  - Demonstrate, adapt, and articulate thoughts and ideas effectively using/including oral, written, multimedia, non-verbal, and/or a performance appropriate for a particular audience.
  - Receive, understand and process information effectively and with consideration for others through active speaking and listening.

- Self-Directed and Lifelong Learner
  - Apply knowledge to set goals, make decisions, and assess new opportunities.
  - Demonstrates initiative, reliability and concern for quality results/solutions/resources/information within time constraints as applicable.
  - Demonstrate flexibility in thinking/problem-solving/etc. including the ability to incorporate new ideas and revise.

EARTH & ENERGY SYSTEMS

COURSE DESCRIPTION
In this lab based science course, students will examine evidence and processes governing the formation and history of Earth.

SEMESTER AT-A-GLANCE		
Unit & Big Ideas	Performance Expectation	Disciplinary Core Ideas
Unit: Earth History		
• Earth's Formation	HS-ESS1-6	ESS1.C; PS1.C
• Earth's Surface Processes	HS-ESS1-5 HS-ESS2-1 HS-ESS2-3 HS-ESS2-5	ESS2.B; ESS1.C; PS1.C; PS4.A ESS2.A; ESS2.B ESS2.A; ESS2.B
Unit: Global Climate Change		
• Earth Systems	HS-ESS2-2	ESS2.A ESS2.D
• Climate Change	HS-ESS2-4 HS-ESS2-5 HS-ESS2-6 HS-ESS3-5	ESS1.B ESS2.C ESS3.D
• The Carbon Cycle	HS-ESS2-6	ESS2.D

NEXT GENERATION SCIENCE STANDARDS
Standards for this course are taken from the Next Generation Science Standards* (NGSS). The following three distinct dimensions combine to form each standard: ➢ Disciplinary Core Ideas - Disciplinary Core Ideas (DCIs) are the key ideas in science that have broad importance within or across multiple science or engineering disciplines. These core ideas build on each other as students progress through grade levels and are grouped into the following four domains: Physical Science, Life Science, Earth and Space Science, and Engineering.

- Science and Engineering Practices - Science and Engineering Practices (SEPs)describe what scientists do to investigate the natural world and what engineers do to design and build systems. The practices better explain and extend what is meant by "inquiry" in science and the range of cognitive, social, and physical practices that it requires. Students engage in practices to build, deepen, and apply their knowledge of core ideas and crosscutting concepts.

- Cross Cutting Concepts - Crosscutting Concepts (CC) help students explore connections across the four domains of science, including Physical Science, Life Science, Earth and Space Science, and Engineering Design. When these concepts, such as "cause and effect", are made explicit for students, they can help students develop a coherent and scientifically-based view of the world around them.

*https://www.nextgenscience.org

CBCI Science Unit Planning Template

Grade: 9/10
Unit Name: Earth History
Conceptual Lens: Stability and Change

Strand 1: Physical Science

- Concepts & Skills (with reference to NGSS Standard)
    - Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. (HS-PS4-4)
- Enduring Understandings
    - Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials.
    - Geologists use seismic waves and their reflection at the interfaces between layers to probe structures deep in the planet.
- Essential Questions
    - How can we determine the age of objects found in the earth's surface?
    - How do we know what is inside the earth?

Strand 2: Life Science (N/A)

Strand 3: Earth and Space Science

- Concepts & Skills (with reference to NGSS Standard)
    - Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (HS-ESS1-6)
    - Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-ESS1-5)
- Enduring Understandings
    - Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history.
    - Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and

meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.
    - Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
    - The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics.
- Essential Questions
    - How has the Earth changed in the past, and how will it change in the future?
    - How does the makeup of the Earth affect the planet's functions?
    - What role does water play in Earth's history?

Strand 4: Engineering and Technology (N/A)

UNIT: EARTH HISTORY

Unit Overview
Encompasses the processes that drive Earth's conditions and its continual evolution (i.e., change over time). It addresses the planet's large-scale structure and composition, describes its individual systems, and explains how they are interrelated. It also focuses on the mechanisms driving Earth's internal motions and their role in the planet's systems and surface processes.

Unit At-a-Glance		
Big Ideas	**Performance Expectations**	**Disciplinary Core Ideas**
Earth's Formation	HS-ESS1-6	ESS1.C; PS1.C
Earth's Surface Processes	HS-ESS1-5 HS-ESS2-1 HS-ESS2-3 HS-ESS2-5	ESS2.B; ESS1.C; PS1.C; PS4.A ESS2.A; ESS2.B ESS2.A; ESS2.B

Big Idea: Earth's Formation

Performance Expectation: HS-ESS1-6

Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.

[Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.]

Disciplinary Core Ideas

UNIT: EARTH HISTORY

ESS1.C: The History of Planet Earth

- Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.

PS1.C: Nuclear Processes

- Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. *(secondary)*

Observable Outcomes

- Students can use reasoning to construct an account of Earth's formation and early history that includes that:
    - The Earth formed along with the rest of the solar system 4.6 billion years ago [evidence: Radiometric ages of lunar rock and meteorites point to an origin of the solar system 4.6 billion years ago while radiometric dating of the oldest rocks on Earth point to the creation of a solid Earth crust about 4.4 billion years ago]
    - The early Earth was bombarded by impacts just as other objects in the solar system were bombarded. [evidence: observations of the size and distribution of impact craters on the surface of Earth compared to the surfaces of solar system objects (e.g., the moon, Mercury, and Mars) can be used to infer that Earth had many impact craters early in its history]
    - Erosion and plate tectonics on Earth have destroyed much of the evidence of this bombardment, explaining the relative scarcity of impact craters on Earth. [evidence: the relative lack of impact craters and the difference in age of most rocks on Earth compared to other bodies in the solar system can be attributed to processes such as volcanism, plate tectonics, and erosion that have reshaped Earth's surface]

Key Terms

Accretion, static electric forces, gravitational pull, iron, nickel, radiometric dating, amphibolites, banded-iron formation,

Suggested Phenomena

Meteorite and asteroid impact crater images and crater impact lab.

UNIT: EARTH HISTORY

- Driving question possibilities: What happens to the mass of the meteorite and/or planet after the impact? If planets form from meteorite and asteroid impacts, how did the meteorites and asteroids form?

Big Idea: Earth's Interior and Earth's Surface Processes		
PE #	Performance Expectation	Disciplinary Core Ideas
HS-ESS1-5	**Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.** [Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust decreasing with distance away from a central ancient core of the continental plate (a result of past plate interactions).]	**ESS1.C: The History of Planet Earth** • Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. **ESS2.B: Plate Tectonics and Large-Scale System Interactions** • Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. *(ESS2.B Grade 8 GBE) (secondary)* **PS1.C: Nuclear Processes** • Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. *(secondary)*

UNIT: EARTH HISTORY

HS-ESS2-3	Develop a model based on evidence of Earth's interior ***to describe the cycling of matter by thermal convection.*** [Clarification Statement: Emphasis is on mantle convection and the resulting plate tectonics. Examples of records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core)]	**ESS2.A: Earth Materials and Systems** • Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior. **ESS2.B: Plate Tectonics and Large-Scale System Interactions** • The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection. **PS4.A: Wave Properties** • Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. (secondary to HS-ESS2-3)
HS-ESS2-1	**Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.** [Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and	**ESS2.A: Earth Materials and Systems** • Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. **ESS2.B: Plate Tectonics and Large-Scale System Interactions** • Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. *(ESS2.B Grade 8 GBE)*

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	destructive mechanisms (such as weathering, mass wasting, and coastal erosion).] [*Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.*]	
HS-ESS2-5	Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]	**ESS2.C** - The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (HS-ESS2-5)
Observable Outcomes		

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- Students can develop a model (i.e., graphical, verbal, or mathematical) in which they identify and describe the components based on both seismic and magnetic evidence (e.g., the pattern of the geothermal gradient or heat flow measurements) from Earth's interior, including:
  - Earth's interior in cross-section and radial layers (crust, mantle, liquid outer core, solid inner core) determined by density;
  - The plate activity in the outer part of the geosphere;
  - Radioactive decay and residual thermal energy from the formation of the Earth as a source of energy;
  - The loss of heat at the surface of the earth as an output of energy;
  - The process of convection that causes hot matter to rise (move away from the center) and cool matter to fall (move toward the center).
- Students can describe the relationships between components in the model, including:
  - Energy released by radioactive decay in the Earth's crust and mantle and residual thermal energy from the formation of the Earth provide energy that drives the flow of matter in the mantle.
  - Thermal energy is released at the surface of the Earth as new crust is formed and cooled.
  - The flow of matter by convection in the solid mantle and the sinking of cold, dense crust back into the mantle exert forces on crustal plates that then move, producing tectonic activity.
  - The flow of matter by convection in the liquid outer core generates the Earth's magnetic field.
  - Matter is cycled between the crust and the mantle at plate boundaries. Where plates are pushed together, cold crustal material sinks back into the mantle, and where plates are pulled apart, mantle material can be integrated into the crust, forming new rock.

- Students can describe connections between the properties of water and its effects on Earth materials

- Students can develop an investigation plan, describe the data that will be collected and the evidence to be derived from the data, including
  - mechanical effects of water on Earth materials that can be used to infer the effect of water on Earth's surface processes.
  - chemical effects of water on Earth materials that can be used to infer the effect of water on Earth's surface processes

- In their investigation plan, students can
  - describe how the data collected will be relevant to determining the effect of water on Earth materials and surface

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processes
  - include a means to indicate or measure the predicted effect of water on Earth's materials or surface processes

- Students can evaluate the accuracy and precision of the collected data, whether the data can be used to infer the effect of water on processes in the natural world, and students refine the plan to produce more accurate and precise data if necessary

Key Terms
Plate tectonics, tectonic uplift, erosion, seismic waves, seismograph/gram, refraction, irreversible, temporal, spatial, inner core, outer core, crust, mantle, continental crust, oceanic crust, sea-floor spreading, isotope, thermal convection, radioactive decay, weathering, rock strata, continental boundary, ocean trench, recrystallization, mass wasting, radiometric dating,

Suggested Phenomena

Teach concept of refraction to understand p & s waves

Additional Resources

https://phet.colorado.edu/en/simulation/legacy/radioactive-dating-game
Explore and measure decay rates, radiometric dating, fossil layers.

https://phet.colorado.edu/en/simulation/legacy/plate-tectonics
Explore features at plate boundaries and plate movements that cause them. Compare with global maps of Earth features.

https://phet.colorado.edu/en/simulation/glaciers
Observe glacier properties and movements with resulting changes to land formations.

https://phet.colorado.edu/en/simulation/legacy/soluble-salts
Investigate solubility and concentration to enhance investigation of chemical weathering.

ADI in Earth and Space Science Lab#6 (Plate Interactions): How is the Nature of the Geologic Activity that is Observed near a Plate Boundary Related to the Type and Plate Interaction that Occurs at that Boundary? (though explicitly linked to MS History of

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Earth PEs, with modification this can be used to address these DCIs)
ADI in Earth and Space Science Lab#7 (Formation of Geologic Features): How Can We Explain the Growth of the Hawaiian Archipelago Over the Past 100 Million Years?
ADI in Earth and Space Science Lab #10 (Deposition of Sediments): How Can We Explain the Deposition of Sediments in Water?
ADI in Earth and Space Science Lab #11 (Soil Texture and Soil Water Permeability): Soil Texture and Soil Water Permeability?

CBCI Science Unit Planning Template

Grade: 9/10
Unit Name: Global Climate Change
Conceptual Lens: Cause and Effect

Strand 1: Physical Science (N/A)

Strand 2: Life Science (N/A)

Strand 3: Earth and Space Science

- Concepts & Skills (with reference to NGSS Standard)
  - Use a model to provide mechanistic accounts of phenomena. (HS-ESS2-4)
  - Analyze data using computational models in order to make valid and reliable scientific claims. (HS-ESS3-5)
- Enduring Understandings
  - The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.
  - The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities.
  - Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth.
  - 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.
  - Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen
- Essential Questions
  - How has Earth's climate changed over time?
  - What are the causes of climate change?
  - How can we model the causes of climate change?

Strand 4: Engineering and Technology (N/A)

UNIT: GLOBAL CLIMATE CHANGE

Unit Overview
In this lab-based unit, students investigate the relationships between several variables that affect global climate through data analysis and modeling. These variables include interactions of the geosphere, hydrosphere, and atmosphere through the geochemical processes of the carbon cycle, with inputs of energy from the sun. Global climate models depend on the amounts of human-generated greenhouse gases that are absorbed by the ocean and biosphere and therefore involve complex feedbacks among Earth's systems.

Unit At-a-Glance		
Big Ideas	**Performance Expectations**	**Disciplinary Core Ideas**
The Earth's Systems	HS-ESS2-2	ESS2.A ESS2.D
Climate Change	HS-ESS2-4 HS-ESS2-5 HS-ESS2-6 HS-ESS3-5	ESS1.B ESS2.C ESS3.D
The Carbon Cycle	HS-ESS2-6	ESS2.D

Big Idea: The Earth's Systems		
PE #	Performance Expectation	Disciplinary Core Idea
HS-ESS2-2	Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.	**ESS2.D** - The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.

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	[Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples taken from other system interactions, could include how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.] Students do not need to specifically need to know the composition of the atmosphere	(HS-ESS2-2) **ESS2.A** - Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes (HS-ESS2-2)

Observable Features

- Students can organize data that represent measurements of changes in hydrosphere, cryosphere, atmosphere, biosphere, or geosphere in response to a change in Earth's surface and can describe what each data set represents
- Students use tools, technologies, and/or models to analyze the data and identify and describe relationships, including 1) the relationships between the changes in one system and changes in another (or within the same) Earth system; and 2) possible feedbacks, including one example of feedback to the climate.
- Student can analyze data to identify effects of human activity and specific technologies on Earth's systems

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- Students can use data to
  - Describe a mechanism for the feedback between two of Earth's systems and whether the feedback is positive or negative, increasing (destabilizing) or decreasing (stabilizing) the original changes
  - Describe a particular unanticipated or unintended effect of a selected technology on Earth's systems if present.

- Students can include explain how limitations, accuracy, or bias in the data resulting from choice of sample, scale, instrumentation, etc. may affect the interpretation of the data.

Key Terms
Glacier, air movement, ocean circulation, longitude, latitude, biosphere, atmospheric circulation, convection, radiation, carbon dioxide, methane, climate change, atmosphere, greenhouse gases, geoscience, sea level, mean surface temperature, reflection, absorption, electromagnetic radiation, feedback

Suggested Phenomenon

- Farming causes loss of forest
- Loss of wetlands
- The permafrost in the Arctic melts

Additional Resources

ADI in Earth and Space Science Lab#18 (Carbon Dioxide Levels in the Atmosphere): How has the Concentration of Atmospheric Carbon Dioxide Changed Over Time? (although specifically aligned to MS ESS3-5, this activity can be modified to address these PEs)

The Global Climate Budget
https://cleanet.org/resources/43024.html
This simulation allows the user to project CO_2 sources and sinks by adjusting the points on a graph and then running the simulation to see projections for the impact on atmospheric CO_2 and global temperatures.

UNIT: GLOBAL CLIMATE CHANGE

Big Idea: Climate Change		
PE #	Performance Expectation	Disciplinary Core Idea
HS-ESS2-4	Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. [Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] Students do not need to know the chemical mechanisms of fossil fuel combustion or ozone depletion	**ESS2.A** - The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (HS-ESS2-4) **ESS1.B** - Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (secondary to HS-ESS2-4) **ESS2.D** - The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS-ESS2-4),(secondary to HS-ESS2-2) Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-4)

Observable Features

- From the given model, students can identify and describe the components of the model relevant for their mechanistic descriptions. Given models include at least one factor that affects the input of energy, at least one factor that affects the

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output of energy, and at least one factor that affects the storage and redistribution of energy. Factors are derived from the following list:
  - Changes in Earth's orbit and the orientation of its axis;
  - Changes in the sun's energy output;
  - Configuration of continents resulting from tectonic activity;
  - Ocean circulation; Atmospheric composition (including amount of water vapor and CO_2);
  - Atmospheric circulation;
  - Volcanic activity;
  - Glaciation;
  - Changes in extent or type of vegetation cover;
  - Human activities.

- From the given model, students can identify the relevant different time scales on which the factors operate.

- Students identify and describe*the relationships between components of the given model, and organize the factors from the given model into three groups
  - Those that affect the input of energy
  - Those that affect the output of energy
  - Those that affect the storage and redistribution of energy

- Students can describe the relationships between components of the model as either causal or correlational

- Students use the given model to provide a mechanistic account of the relationship between energy flow in Earth's systems and changes in climate, including:
  - The specific cause and effect relationships between the factors and the effect on energy flow into and out of Earth's systems; and The net effect of all of the competing factors in changing the climate

Key Terms
Earth's orbit, Earth's axis of rotation, cyclic, interdependent, solar radiation, solar flare, chemical processes, biosphere, atmospheric circulation, ocean circulation, climate patterns, carbon dioxide, ice age, tectonic cycles, climate change, sea level, glacier, atmospheric composition, hydrosphere, greenhouse gases, global warming, fossil fuel, human impact, combustion, electromagnetic radiation, reflection, absorption, radiation

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Suggested Phenomenon

- Volcanic eruption
- Changes to Earth's orbit: glaciers
- Tilt of planet's axis/ice ages/seasons
- Ice core data of atmospheric composition

Additional Resources

Very, very simple climate model from NOAA. Flash-based interactive climate model with link to page of instructions for teachers.
https://scied.ucar.edu/simple-climate-model

How the World Passed a Carbon Threshold and Why it Matters:
https://e360.yale.edu/features/how-the-world-passed-a-carbon-threshold-400ppm-and-why-it-matters

PhET Greenhouse Effect Sim
https://phet.colorado.edu/en/simulation/legacy/greenhouse
Take simulated data to examine how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures. Use the model to examine the effects of atmospheric changes on climate and make predictions.

ADI in Earth and Space Science Lab#17 (Factors that Affect Global Temperature): How Do Cloud Cover and Greenhouse Gas Concentration in the Atmosphere Affect the Surface Temperature of Earth? (note: utilizes PhET Greenhouse Effect Sim)

UNIT: GLOBAL CLIMATE CHANGE

Big Idea: Climate Change		
PE #	Performance Expectation	Disciplinary Core Idea
HS-ESS2-5	Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]	**ESS2.C** - The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (HS-ESS2-5)

Observable Features

- Students can describe connections between the properties of water and its effects on Earth surface processes
- Students can develop an investigation plan, describe the data that will be collected and the evidence to be derived from the data, including
    - the heat capacity of water; the density of water in its solid and liquid states; and the polar nature of the water

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molecule due to its molecular structure
  - the effect of the properties of water on energy transfer that causes the patterns of temperature, the movement of air, and the movement and availability of water at Earth's surface

- In their investigation plan, students can
  - describe how the data collected will be relevant to determining the effect of water on Earth surface processes
  - include a means to indicate or measure the predicted effect of water on Earth's surface processes

- Students can evaluate the accuracy and precision of the collected data, whether the data can be used to infer the effect of water on processes in the natural world, and students refine the plan to produce more accurate and precise data if necessary

Key Terms
Liquid, solid, freezing, melting, heat capacity, release, absorb, transmit, expand, contract, dissolve, viscosity, density, polar molecule, erosion

Suggested Phenomena

Additional Resources

https://www.physicsclassroom.com/class/light/Lesson-2/Light-Absorption,-Reflection,-and-Transmission

https://en.wikipedia.org/wiki/Electromagnetic_absorption_by_water#/media/File:Absorption_spectrum_of_liquid_water.png

ADI in Earth and Space Science Lab #12 (Cycling of Water on Earth): Why Do the Temperature and Surface Area to Volume Ratio of a Sample of Water Affect Its Rate of Evaporation?

ADI in Earth and Space Science Lab #19 (Differences in Regional Climate): Why Do Two Cities Located at the Same Latitude and

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Near a Body of Water Have Such Different Climates? (though specifically aligned to MS ESS2-6, this can be aligned to address this DCI

Big Idea: Climate Change		
PE #	Performance Expectation	Disciplinary Core Idea
HS-ESS3-5	Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature)	**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. (HS-ESS3-5)

Observable Features

- Students can organize data (e.g., with graphs) from global climate models (e.g., computational simulations) and climate observations over time that relate to the effect of climate change on the physical parameters or chemical composition of the atmosphere, geosphere, hydrosphere, or cryosphere; they can describe what each data set represents
- Students can analyze the data and identify and describe relationships within the data sets, including changes over time on multiple scales; and relationships between quantities in the given data
- Students can use their analysis of the data to describe a selected aspect of present or past climate and the associated physical parameters (e.g., temperature, precipitation, sea level) or chemical composition (e.g., ocean pH) of the atmosphere, geosphere, hydrosphere or cryosphere.
- Students can describe whether the predicted effect on the system is reversible or irreversible

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- Students can identify one source of uncertainty in the prediction of the effect in the future of a selected aspect of climate change
- In their interpretation of the data, students can make a statement regarding how variation or uncertainty in the data may affect the interpretation of the data; and identify the limitations of the models that provided the simulation data and ranges for their predictions.

Key Terms

Suggested Phenomena

Additional Resources

PhET Greenhouse Sim
https://phet.colorado.edu/en/simulation/legacy/greenhouse
Take simulated data to examine how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures.

What's the Future of Earth's Climate
https://cleanet.org/resources/43831.html
This is a series of 5 guided-inquiry activities that examine data and models that climate scientists use to attempt to answer the question of Earth's future climate.

Using a mass balance model to understand carbon dioxide and its connection to global warming
https://cleanet.org/resources/41868.html
Students explore the increase in atmospheric carbon dioxide over the past 40 years with an interactive online model. They use the model and observations to estimate present emission rates and emission growth rates. The model is then used to estimate future levels of carbon dioxide using different future emission scenarios. These different scenarios are then linked by students to climate model predictions also used by the Intergovernmental Panel on Climate Change.

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Big Idea: The Carbon Cycle

Performance Expectation: HS-ESS2-6

Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

[Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.]

Disciplinary Core Ideas:

ESS2.D: Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen

Observable Features

- Students can use evidence to develop a model in which they identify the relative concentrations of carbon present in the hydrosphere, atmosphere, geosphere and biosphere, and represent carbon cycling from one sphere to another
- In the model, students represent and describe the following relationships between components of the system, including the biogeochemical cycles that occur as carbon flows from one sphere to another, the relative amount of and the rate at which carbon is transferred between spheres, the capture of carbon dioxide by plants, and the increase in carbon dioxide concentration in the atmosphere due to human activity and the effect on climate
- Students can use the model to explicitly identify the conservation of matter as carbon cycles through various components of Earth's systems and identify the limitations of the model in accounting for all of Earth's carbon

Key Terms
Biosphere, hydrosphere, geosphere, atmosphere, biogeochemical cycles, conservation of matter

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Suggested Phenomena

Additional Resources

Understanding the Carbon Cycle - A Jigsaw Approach
https://cleanet.org/resources/41877.html
This is a jigsaw activity in which students are assigned to research one step out of five in the geochemical process stages of the organic carbon cycle. Students then teach their step in cross-step groups until everyone understands all five process stages.

Components of the Carbon Cycle
https://cleanet.org/resources/43457.html
A simplified visual of the terrestrial carbon cycle side by side with the ocean carbon cycle. Fluxes and reservoirs expressed in gigatons are included

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