Teaching the History of the Oceans and Atmosphere using the CLEAN-NGSS Unit Planning Template

Unit Title:	History of the Oceans & Atmosphere		
Grade Level and Class:	High School Environmental & Earth Science	**Instructional Time:**	2-week unit

1. Select the NGSS Performance Expectation(s) (PEs) based on grade level and content-focus and list the learning objectives.

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's systems.

HS-ESS2-7. Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.

Students will ...

1. Analyze data and graphs showing changes over time of carbon dioxide, oxygen, and temperature
2. Identify correlations between geologic, biologic and impacts with the conditions of the oceans and atmosphere.
3. Model possible feedbacks between Earth's systems that create changes in the atmosphere and oceans.
4. Develop and present their findings regarding the mechanisms of change and the feedbacks.

2. What phenomena, problem, or project would best suit the PE(s)?
(Learn more about phenomena)

There is a preponderance of data indicating that the Earth's Oceans and Atmosphere are changing. Has this happened in the past? What may have caused the oceans and atmosphere to change? What data supports our understanding of the history of oceanic and atmospheric chemistry, structure and dynamics? How can understanding past changes inform us on current changes?

Driving Questions:

How do changes in Earth's Atmosphere affect changes in Earth's Oceans? (HS-ESS2-2)

How do changes in Earth's Atmosphere affect changes in Earth's Oceans? (HS-ESS2-7)

3. Describe an overview of how the phenomena, problem, or project would best suit the PE(s).
(Revise, as needed)

Oceanic, atmospheric, biologic and geologic processes all drive the climate system and result in a regional differences in climates

on Earth. Many climatic processes such as the greenhouse effect and the carbon cycle are the result of interplay between the "spheres" of the Earth system (atmosphere, cryosphere, geosphere, biosphere). Feedbacks between various components work to exacerbate or mitigate changes to the climate. Oceanic processes are integral in the distribution of heat, absorption of CO2,and changes in circulation patterns.

4. What type of strategy works best for teaching and learning about the phenomena, problem, or project?
(For ideas, see the Teaching Strategies for Units)

Data-based

5. Identify (unpack) the Performance Expectation(s) components embedded in the PE(s) in the NGSS Matrix.
(For guidance, see Access the NGSS Science Standards by Topic):

HS-ESS2-2

Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Crosscutting Concepts (CCC)
Analyzing and Interpreting Data: Analyze data using tools, technologies, and/or models (e.g. computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution **Developing and Using Models:** Develop a model based on evidence to illustrate the interrelationships between systems or between components of a system.	**Earth Materials and Systems** (HS-ESS2.A) Earth's systems, being dynamic and interacting cause feedback effects that can increase or decrease the original changes **Weather and Climate** (HS-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.	**Stability and Change:** Feedback (negative or positive) can stabilize or destabilize a system. **Connections to Engineering, Technology, and Applications of Science - Influence of Science, Engineering, and Technology on Society and the Natural World:** New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

HS-ESS2-7

Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Crosscutting Concepts (CCC)
Engaging in Argument from Evidence: Construct an oral and written argument or counter-arguments based on data and evidence.	**Weather and Climate** (HS-ESS2.D) Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. **Biogeology** (HS-ESS2.E) The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.	**Stability and Change:** Much of science deals with constructing explanations of how things change and how they remain stable

6. How will you assess students' learning of the PEs with summative assessments and/or rubrics?

Summative Assessment: Students are given an article to read about a past extinction. Students answer questions specific to the article.

Example: The Permian Extinction was rapid and caused by an increase in CO_2: **An extinction in the blink of an eye -** MIT researchers find that the end-Permian extinction happened in 60,000 years — much faster than earlier estimates. Jennifer Chu, MIT News Office. February 10, 2014 (http://news.mit.edu/2014/an-extinction-in-the-blink-of-an-eye-0210)

1. The Permian Extinction was most likely caused by what event? What is the evidence for this?
2. What are natural sources of carbon dioxide?
3. How does the atmosphere change when carbon dioxide concentrations change?
4. When carbon dioxide concentrations increase in the atmosphere, how does ocean chemistry change?
5. What is the impact of changing ocean chemistry on marine organisms?
6. How does temperature affect the exchange of gases between the oceans and the atmosphere?
7. How do marine organisms respond to increased ocean temperatures?
8. What are the positive and negative feedbacks that increase and/or decrease the effects of increased atmospheric carbon dioxide concentrations?

7. Create an instructional plan by building a unit storyline:

Assess Students' Prior Knowledge

- Develop a plan to determine students' prior knowledge (e.g. pre-test, class discussion, etc.) based on the NGSS standards listed below that students should have learned throughout elementary school:

MS-ESS1-4: The History of the Earth's System - Students know how to construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6 billion year history.

- **Science & Engineering Practice:** Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
- **Disciplinary Core Ideas:**
  - The geologic time scale interpreted from rock strata provides a way to organize Earth's history.
  - Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.
- **Crosscutting Concepts:** Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Identify Learning Activities

Select learning activities from CLEAN (NGSS and CLEAN at a Glance and Search the CLEAN Collection by NGSS Topic) and other resources that build towards the PEs.

HS-ESS2-2:

- HHMI EarthViewer App Activity http://www.hhmi.org/biointeractive/earthviewer
- The Earth's Heat Budget http://cleanet.org/resources/41888.html
- PETM: Unearthing Ancient Climate Change http://cleanet.org/resources/42835.html
- Natural Climate Change http://cleanet.org/resources/43820.html
- Milankovitch Cycles and Climate http://cleanet.org/resources/43016.html and https://www.ncdc.noaa.gov/paleo/ctl/clisci100k.html#cycles
- From Mud to Molecules: What Deep Sea Sediments Can Tell Us about Past Climates http://cleanet.org/resources/43162.html
- Abrupt Events of the Past 70 Million Years – Evidence from Scientific Ocean Drilling http://cleanet.org/resources/47889.html
- From Mud to Molecules: What Deep Sea Sediments Can Tell Us about Past Climates http://cleanet.org/resources/43162.html
- Abrupt Events of the Past 70 Million Years – Evidence from Scientific Ocean Drilling http://cleanet.org/resources/47889.html
- Ice Core Secrets Could Reveal Answers to Global Warming http://cleanet.org/resources/45159.html
- Antarctic - Vostok Ice Core http://cleanet.org/resources/42745.html
- Arctic - Greenland Ice sheet project 2: A record of climate change http://cleanet.org/resources/43452.html

- More than Mud https://www.youtube.com/watch?v=GZ3NlESSk40
- Paleoclimate Reconstructions using lake varves http://cleanet.org/resources/43394.html
- Sea Change Part 1: In the Field http://cleanet.org/resources/45133.html
- Sea Change Part 2: In the Lab http://cleanet.org/resources/45162.html
- Sea Change Part 3: Interpreting the Results http://cleanet.org/resources/45149.html
- Off Base - Acidity of oceans http://cleanet.org/resources/41828.html
- An extinction in the blink of an eye http://news.mit.edu/2014/an-extinction-in-the-blink-of-an-eye-0210

HS-ESS2-7:

- Lehigh's Interactive Geologic Timeline Activity, http://cleanet.org/resources/43395.html
- HHMI EarthViewer App Activity http://www.hhmi.org/biointeractive/earthviewer
- The Earth's Heat Budget http://cleanet.org/resources/41888.html
- PETM: Unearthing Ancient Climate Change http://cleanet.org/resources/42835.html
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Develop Unit Timeline and Formative & Summative Assessments

Day 1 - Engage: Introduce students to the HHMI Earthviewer App at http://www.hhmi.org/biointeractive/earthviewer

- Have students working in groups of 2-4 to encourage conversations while they investigate the App.
- Give students an opportunity to play with the app and learn how it works. After a few minutes, encourage them to watch the tutorial to figure out how to best manipulate the app.
- Have students toggle through the different time scales and discuss the resolution of data that is available.
- Compare parameters of our current climate with Earth's different past climates by examining the different data sets over time and have students generate questions regarding the relationships between the different charts
    - Temperature
    - Oxygen
    - Carbon Dioxide
    - Day Length
    - Solar Luminosity
    - Biodiversity
- With the whole class, record students' questions and have students sort the questions into different categories.
    - Temperature vs. CO_2, Day Length, and Solar Luminosity
    - Biodiversity vs. CO_2, O_2, and Solar Luminosity
    - O_2 vs. CO_2 and Biodiversity

Alternative Engage activity: Lehigh's Interactive Geologic Timeline Activity at http://cleanet.org/resources/43395.html

Formative Assessment: Students have generated a list of questions in which they correctly identify correlations and postulate possible cause and effect relationships.

Days 2-3 - Explore Electromagnetic Radiation:

The Earth's Heat Budget http://cleanet.org/resources/41888.html Hands-on laboratory activity that allows students to investigate the effects of distance and angle on the input of solar radiation at Earth's surface, the role played by albedo, the heat capacity of land and water, and how these cause the seasons. Students predict radiative heating based on simple geometry and experiment to test their hypotheses.

Days 4-6 - Explore how we know about the history of Earth's atmosphere and oceans:

To show how scientists use different lines of evidence to support theories, start with **PETM: Unearthing Ancient Climate Change** (http://cleanet.org/resources/42835.html)

- Set up Jigsaw https://www.jigsaw.org/
    - Divide students into Home Groups of 5-6 students. Within the Home Groups, have students count off. Students will be reporting back to the students in their Home Groups.

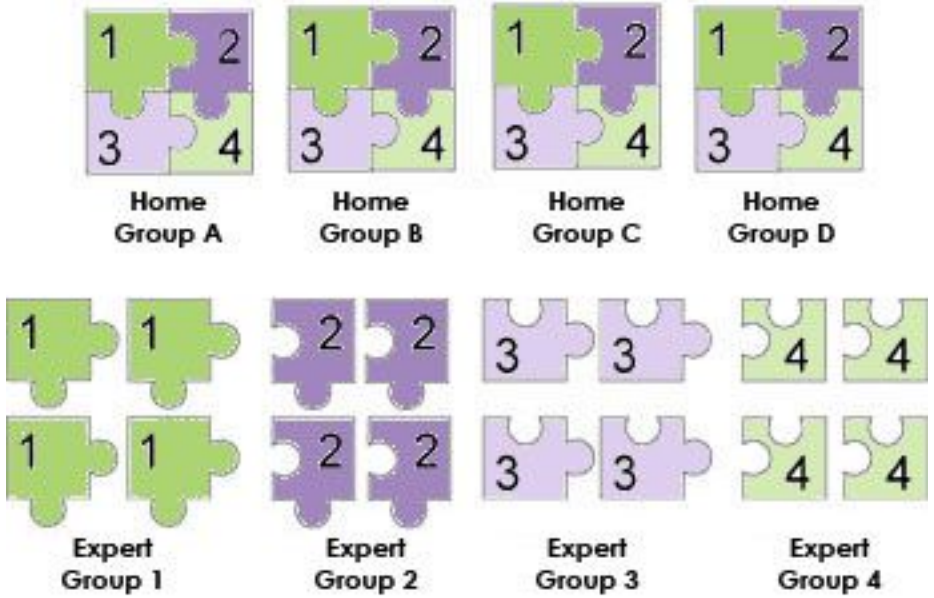

Diagram from http://edtech2.boisestate.edu/reilleyd/502/jigsaw.html

- Regroup students by their numbers to create “Expert Groups”.
  - Each Expert Group gets a different set of data to analyze and activity to complete.
  - Each Expert Group develops a claim that states how changes and trends in their data demonstrate feedbacks between at least two Earth Systems.
- When their research is done and students have completed their activities, have them go back to their Home Groups to present on what they have learned.
- After all students have presented to their Home Groups, students will
  - Identify the similarities in findings for each of the data sets
  - Summarize how we understand changes in Earth’s atmosphere and oceans
  - Students reconcile the different claims made by members in their Home Group and support a new claim using data and evidence.

- Data sets & activities
  - Astronomic Forces -
    - Video: Natural Climate Change http://cleanet.org/resources/43820.html
    - Activity: Milankovitch Cycles and Climate http://cleanet.org/resources/43016.html and https://www.ncdc.noaa.gov/paleo/ctl/clisci100k.html#cycles

- Fossil Record
  - Video: The Fossil Record of Warmer Climates in the Past http://thiniceclimate.org/blog/details/2027/the-fossil-record-of-warmer-climates-in-the-past-martin-brasier
- Sea Sediments
  - Video: From Mud to Molecules: What Deep Sea Sediments Can Tell Us about Past Climates http://cleanet.org/resources/43162.html
  - Activity: Abrupt Events of the Past 70 Million Years – Evidence from Scientific Ocean Drilling http://cleanet.org/resources/47889.html
- Ice Cores
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- Lake Sediments
  - Video - More than Mud https://www.youtube.com/watch?v=GZ3NlESSk40
  - Activity - Paleoclimate Reconstructions using lake varves http://cleanet.org/resources/43394.html

Day 7 - Explain: How are the changes in Earth's Atmosphere and Oceans related?

- Sea Change Part 1: In the Field http://cleanet.org/resources/45133.html This video is the first of a three-video series from the Sea Change project. It features the field work of scientists from the US and Australia looking for evidence of sea level rise during the Pliocene era when Earth was (on average) about 2 to 3 degrees Celsius hotter than it is today.
- Sea Change Part 2: In the Lab http://cleanet.org/resources/45162.html This video is the second of a three-video series in the Sea Change project, which follows the work of Dr. Maureen Raymo, paleogeologist at Columbia University's Lamont-Doherty Earth Observatory, who travels with fellow researchers to Australia in search of evidence of sea level that was once higher than it is today.
- Sea Change Part 3: Interpreting the Results http://cleanet.org/resources/45149.html This video is the third in a three-part series by the Sea Change project, about scientists' search for Pleiocene beaches in Australia and elsewhere to establish sea level height during Earth's most recent previous warm period. This segment features the research of Jerry Mitrovica, Harvard geophysicist.

Days 8-9 - Extension: The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.

- Off Base - Acidity of oceans http://cleanet.org/resources/41828.html

- This lesson guides a student inquiry into properties of the ocean's carbonate buffer system, and how changes in atmospheric carbon dioxide levels may affect ocean pH and biological organisms that depend on calcification.

Day 10 Evaluate: The Permian Extinction was rapid and caused by an increase in CO_2

9. Give students the article **An extinction in the blink of an eye -** MIT researchers find that the end-Permian extinction happened in 60,000 years — much faster than earlier estimates. Jennifer Chu, MIT News Office. February 10, 2014 (http://news.mit.edu/2014/an-extinction-in-the-blink-of-an-eye-0210)
    - Students are able to identify trends and relationships between different variables in Earth's history that affect both the atmosphere and oceans
    - Students are able to predict how changes in atmospheric CO_2 will affect global temperatures and ocean chemistry
    - Students can identify correlations between geologic, biologic and impacts with the conditions of the oceans and atmosphere.
    - Students can identify and explain possible feedbacks between Earth's systems that create changes in the atmosphere and oceans.

8. Unit Reflection:

- What parts of the unit were a success?
- What were some challenges about the unit?
- How could the unit be changed or improved?

(To be completed after unit instruction)