KAI E‘E - MOUNTING SEAS

Hawai‘i Tsunami and Climate Change Curriculum

Grades 6 and 8: Climate Change

Produced by

The Pacific Tsunami Museum, Hilo, Hawai‘i

in partnership with
The Pacific American Foundation, Kāne‘ohe, Hawai‘i
and the Geophysics Institute, University of Alaska Fairbanks

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Kai E‘e – Mounting Seas

Pacific Tsunami and Climate Change Curriculum

Grade 6 - Climate Change Unit

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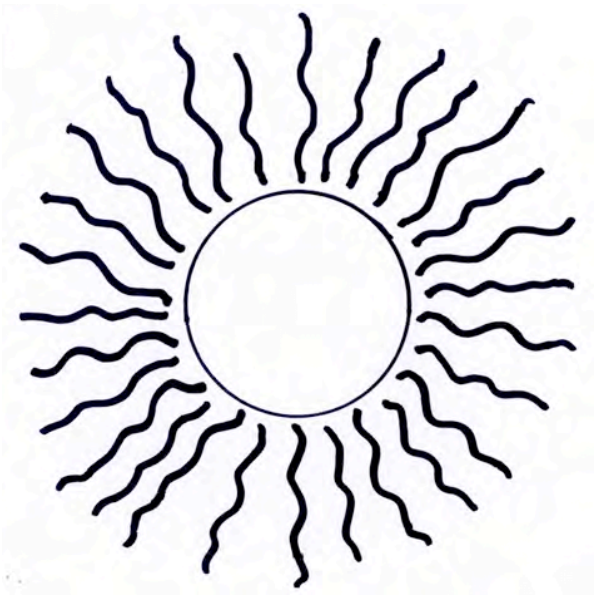


Students begin the Climate Change Unit with an oli (chant). The oli sets a tone of respect and reverence for the elements as we seek to understand the changes to climate that are occurring all around us. Climate change is a complex topic that provides opportunities for students to explore many interrelationships, including the connections between our energy use and changes in the global carbon cycle, temperatures, rainfall patterns, and sea level. This unit is designed as an introduction to climate change with a focus on sea level rise in Hawai'i, and actions that students can take today to reduce their carbon footprints. The essential question for the unit is: *How do we know if Hawai'i's sea level is rising due to global climate change and what can we do about it?*

Assessment

The Unit Map that follows in this Introduction lays out the Hawai'i DOE standards, the Common Core standards, and the Nā Honua Mauli Ola (Hawaiian Guidelines) on which the lessons are designed. A Unit Pre / Post-assessment is provided on page 3. This one-page assessment consists of constructed response items aligned to standard benchmarks and key concepts from the lessons. The assessment is designed to administer at the beginning and at the end of the unit. The standard benchmarks and corresponding lessons for each item on the assessment are indicated on the answer sheet provided on pages 4 - 5.

In addition, the Next Generation Science Standards (NGSS) that correlate with the Hawai'i Content and Performance Standards have been added to the Unit Map, lessons, and rubrics to assist teachers and students in making the transition to these new standards.

A unit summative assessment, which includes an individual and group project, is described in the Learning Log and in Lesson 6, the culminating activity. The rubrics provided with the unit are designed to assess students' culminating projects.

The first five lessons in the unit provide sequential steps to enable the students to successfully complete the culminating projects. The Learning Log pages provided with each lesson serve as a formative assessment. They are designed to be combined into a journal that documents students' learning as they progress through the unit.

The wave graphic that appears on each page is at the top of teacher pages, and at the bottom of student pages so that these pages may be easily identified.

Unit Overview

In Lesson 1, Heating Up!, students examine data from Mauna Loa and conduct demonstrations to explore the role of greenhouse gases in warming the planet. They are introduced to the carbon cycle and ways

that human activities are throwing the cycle out of balance.

In **Lesson 2, Warming and Melting**, students investigate how thermal expansion of the oceans and melting glaciers and ice sheets all contribute to global sea level rise. They develop hypotheses and work with models on a thermal expansion experiment. Students create a chain-of-events scenario depicting how melting of sea ice contributes to global warming.

In **Lesson 3, Carbon Consequences**, students view animated fly-overs of "blue line" maps showing projected sea level rise in Hawai'i by the end of the century. Using the ratio of water depth to the distance offshore where waves first affect the bottom, students predict how projected sea level rise will affect their beach profile. They go to the beach to collect baseline data about local ocean and shoreline conditions and prepare to share their data with others.

Students have an opportunity to learn from their elders in **Lesson 4, Hō'ailona--Signs in Nature**. Student teams interview local fishers and kūpuna about changes they have observed locally over time. Student teams collect data, compile their findings, and correspond with other schools to share information and images about climate change in Hawai'i.

Lesson 5, Energized!, provides students with an opportunity to calculate their carbon footprints and explore ways for Hawai'i to reduce carbon emissions through alternative energy. Students work with mini-solar panels and wind turbines to see how much energy they can capture as they make recommendations for moving away from fossil fuels and generating power from alternative sources for their community.

As students explore ways to apply what they learn about climate change, they will practice the values of kuleana (responsibility) and laulima (working together). These values are demonstrated in the culminating activity, **Lesson 6, Rising Seas**, where students collaborate in teams to answer the unit essential question. Each team reports on two topics: a factor related to climate change, and a form of alternative energy. They select a method to report on their findings to the community including posters, computer presentations, or PSAs. Individually, students write papers to summarize their findings in answer to the unit essential question.

Appendices

The Appendices provided with this unit include in-depth tips for videotaping interviews and articles that supplement the background information provided in each lesson. The articles include the Environmental Protection Agency's summary of climate change indicators in the United States, a briefing sheet on Hawai'i's changing climate provided by Dr. Charles Fletcher of the University of Hawai'i, and Climate Change and Pacific Islands: Indicators and Impacts: Executive Summary.

The materials provided in this unit are designed with the intent of raising student awareness about a topic of vital importance to people living on islands--climate change and rising sea level. By the end of this century, sea level in Hawai'i is projected to rise by one meter. Exploring the complex interactions that lead to climate change and sea level rise and engaging in actions we can take today, provides students with meaningful opportunities that add both rigor and relevance to the curriculum.

KAI E'E GR. 6 UNIT PRE /POST-ASSESSMENT

NAME_____ **DATE**_____
SCHOOL_____

1. The process by which heat transfers from the Sun to the Earth is: (*circle one*) conduction, convection, or radiation.

2. Identify two ways that human activities are increasing greenhouse gases in the atmosphere.

3. Explain how plants change the form of carbon from a gas to a solid in the carbon cycle.

4. Describe two different ways that increases in global air temperatures could lead to sea level rise.

5. Describe at least three ways that the increase in greenhouse gases could affect our shoreline communities in Hawai'i.

6. Identify at least one way that a change in a marine plant or animal provides a clue to climate change in Hawai'i.

7. On the back of this page, identify an alternative energy source for Hawai'i. Explain why switching from fossil fuels to alternative energy could help reduce global warming.

Gr. 6 Unit Pre /Post-Assessment Answer Sheet

Question	Standard / Lesson	Answers	Total Possible Points
1. The process of heat transfer from the Sun to the Earth is: (circle one) conduction, convection, or radiation.	**SC.6.6.1** Compare how heat energy can be transferred through conduction, convection, and *radiation*. Lesson: 1	• Radiation	1 point
2. Identify at least two ways that human activities are increasing greenhouse gases in the atmosphere.	**SC.6.2.1** Explain how technology has an impact on society and science. Lesson 1	• burning fossil fuels • clearing forests • rice cultivation • livestock wastes • decaying wastes from landfills *1 point for each correct response (up to 4)*	4 points
3. Explain how plants change the form of carbon from a gas to a solid in the carbon cycle.	**SC.6.6.5** Explain how matter can change physical or chemical forms, but the total amount of matter remains constant. Lesson 1	• Plants take in carbon dioxide (gas) *(1 point)* in the process of photosynthesis *(1 point)* and create carbohydrates or simple sugars (solids) *(1 point)*	3 points
4. Describe two different ways that increases in global air temperatures could lead to sea level rise.	**SC.6.6.1** Compare how heat energy can be transferred through conduction, convection, and radiation. Lesson 2	• Warming causes expansion of the ocean water which leads to sea level rise. • Warming causes melting of glaciers and ice sheets, which leads to sea level rise. (Note: not the melting of sea ice.) *2 points for each correct response*	4 points

5. Describe three ways that the increase in greenhouse gases could affect our shoreline communities in Hawai‘i.	**SC.6.2.1** Explain how technology has an impact on society and science. Lesson 3	• Sea level rise • Erosion of beaches • Increased threat from tsunamis and storms • Changes in ocean water temperature • Changes in ocean pH *1 point for each correct response (up to 3)*	3 points
6. Identify at least one way that a change in a marine plant or animal provides a clue to climate change in Hawai‘i.	**NHMO.8.1** Be keen observers of their natural environment Lesson 4	• Coral bleaching or changes in timing of fish life cycles *(2 points for one correct response)*	2 points
7. Identify an alternative energy source for Hawai‘i. Explain why switching from fossil fuels to alternative energy could help reduce global warming.	**SC.6.2.2** Explain how the needs of society have influenced the development and use of technologies. Lesson 5 & 6	• Alternative energy sources - any of the following: solar, wind, tidal, biomass, geothermal, hydropower *(1 point)* • Burning fossil fuels releases carbon which leads to increased greenhouse gases and climate change. Harnessing energy from alternative sources such as wind or solar, reduces our carbon emissions. *(2 points)*	3 points
		Total possible points:	20

Grade 6 Unit Map — Climate Change

Essential Question: How do we know if Hawai‘i's sea level is rising due to global climate change and what can we do about it?

Enduring Understandings:

- Greenhouse gases block heat from re-radiating out to space, which warms the planet.
- Humans are increasing greenhouse gases, which affect global climate and sea level.
- Changes in Hawaiian weather and ocean conditions over time are clues to understanding local climate change and sea level rise.
- We can mālama ‘āina by harnessing energy from renewable sources and making lifestyle changes to reduce our carbon footprint and help to slow the process of climate change.

Nā Honua Mauli Ola (NHMO) Cultural Pathways:

‘Ike Pilina - Relationship Pathway
‘Ike Mauli Lāhui: Cultural Identity Pathway
‘Ike Na‘auao - Intellectual Pathway
‘Ike Ho‘okō - Applied Achievement Pathway
‘Ike Honua - Sense of Place Pathway
Values: kuleana (responsibility) and laulima (working together)

Total 50-Minute Class Periods for Unit: 16 - 20

Core Content Areas: Science, Language Arts and Math

Unit Pre / Post-assessment:

Students complete a one-page assessment with constructed response items aligned to standard benchmarks and key concepts addressed in the unit. (Assessment provided in the Unit Introduction)

Culminating Project:

- Write a paper to answer the unit essential question using data collected and facts gathered in an organized manner, with a logical sequence of ideas and relevant, descriptive details.
- Collaborate in teams to research and present to the school community:
  1) a clue to climate change and rising sea level
  2) a form of alternative energy for Hawai‘i; how it transfers and conserves energy and how it compares to fossil fuels.
- Add effective visual displays to their presentations to enhance the development of main ideas.

General Learner Outcomes:

GLO 3: Complex Thinker - Considers multiple perspectives when analyzing and solving a problem

GLO 5: Effective Communicator - Communicates effectively and clearly through speaking, using appropriate forms, conventions, and styles to convey ideas and information

Notes on Next Generation Science Standards (NGSS)

This unit map includes Next Generation Science Standards that correlate with the Hawai‘i Content and Performance Standards (HCPS) in Science. To increase the rigor of the unit and begin making the transition to NGSS, consider adjusting the assessments as suggested on the unit map for each lesson.

Suggestions for adapting the assessments to meet NGSS are also included in the margins next to the Teaching Suggestions within the lessons.

Rubrics for the culminating project have been designed for both HCPS and NGSS benchmarks to assist teachers and students in making the transition to NGSS.

1: Heating Up!

How are human activities contributing to a warming planet? (Make this 2 lessons)

Standards	Benchmarks	Next Generation Science Standards (NGSS)	Key Concepts
Science 6: Nature of Matter and Energy - Energy and its Transformation **Science 2: Nature of Science** - Science, Technology and Society **Language Arts: Writing -** Research to Build and Present Knowledge (W) **ʻIke Mauli Lāhui: Cultural Identity Pathway**	• **SC.6.6.1** Compare how heat energy can be transferred through conduction, convection, and *radiation*. • **SC.6.6.5** Explain how matter can change physical or chemical forms, but the total amount of matter remains constant. • **SC.6.2.1** Explain how technology has an impact on society and science. • **W.6.9** Draw evidence from literary or informational texts to support analysis, reflection, and research. • **NHMO.3.4** Demonstrate culturally appropriate behavior and traditional knowledge skills.	**Energy** **MS-PS3-3** Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. **Matter and Energy in Organisms and Ecosystems** **MS-LS2-3** Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. **Weather and Climate** **MS-ESS3-5** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.	• Radiation, reflection and greenhouse gases • Carbon dioxide increasing - Mauna Loa data • Impact of burning fossil fuels and deforestation • Carbon cycle

Assessments

Students:

- Complete a diagram that illustrates how heat energy re-radiates from Earth back into space and how greenhouse gases absorb heat and warm the planet.
- Illustrate and explain how carbon is released and absorbed as it moves and changes form in a balanced and unbalanced carbon cycle.
- Write a reflection about their personal connection to natural elements and how the needs of society today are impacting the planet.

Assessment Adjustments for NGSS

Students:

- Diagrams of the greenhouse effect include explanatory text describing their models of thermal energy transfer.
- Ask questions to clarify evidence in their reflections.
- Add explanatory text to their illustrations of the carbon cycle to describe the cycling of matter and flow of energy.

Class Periods: 3 - 4

Student Pages

- Unit Pre-assessment
- Student Reading 1
- Learning Logs 1 and 2
- Vocabulary Practice 1
- Student Assessment Overview
- Student Resources

2: Warming and Melting

How is climate change affecting the oceans?

Standards	Benchmarks	Next Generation Science Standards (NGSS)	Key Concepts
Science 6: Nature of Matter and Energy - Energy and its Transformation **Science 1: The Scientific Process** - Scientific Inquiry **'Ike Na'auao - Intellectual Pathway**	• **SC.6.6.1** Compare how heat energy can be transferred through conduction, convection, and *radiation*. • **SC.6.6.5** Explain how matter can change physical or chemical forms, but the total amount of matter remains constant. • **SC.6.1.1** Formulate a testable hypothesis that can be answered through a controlled experiment. • **SC.6.1.2** Use appropriate tools, equipment, and techniques safely to collect, display, and analyze data. • **NHMO.6.14** Continue to develop personal communication, participation and collaboration skills.	**Energy** **MS-PS3-3** Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. **Structure and Properties of Matter** **MS-PS1-4** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when energy is added or removed. **Weather and Climate** **MS-ESS3-5** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.	• Thermal expansion and melting ice causing sea level rise • Loss of reflective ice and snow - accelerating global warming • Melting glaciers and ice sheets and sea level rise • Oceans are carbon sinks - warming oceans less able to absorb carbon dioxide

Assessments

Students:

- Develop a testable hypothesis and complete an investigation to demonstrate how warming water expands, and infer how warming oceans could lead to sea level rise.
- Draw a chain-of-events diagram to explain how melting of glaciers, sea ice, and ice sheets leads to loss of reflective ice and snow, which decreases the Earth's albedo (reflectivity), accelerating global warming and sea level rise.
- Explain how the warming of the ocean affects its ability to absorb CO_2 from the atmosphere.

Assessment Adjustments for NGSS

Students:

- Draw a diagram to demonstrate how adding heat to water causes the water particles to move faster and the water to expand. Infer how this relates to global sea level rise.
- Write questions to clarify evidence about the rise in global temperatures and sea level rise.
- Have students share their questions and conduct research to seek answers.

Class Periods: 3 - 4

Student Pages

- Student Reading 2
- Learning Logs 3 and 4
- Vocabulary Practice 2

3: Carbon Consequences

How is climate change projected to affect shoreline communities In Hawai'i?

Standards	Benchmarks	Next Generation Science Standards (NGSS)	Key Concepts
Science 1: The Scientific Process - Scientific Inquiry **Science 2: Nature of Science -** Science, Technology and Society **Math: Statistics and Probability -** Ratios and Proportional Relationships (RP) **Language Arts: Speaking and Listening -** Comprehension and Collaboration (SL) **'Ike Honua - Sense of Place Pathway**	• **SC.6.1.2** Use appropriate tools, equipment, and techniques safely to collect, display, and analyze data. • **SC6.2.1** Explain how technology has an impact on society and science. • **RP.6.1** Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. • **RP.6.3** Use ratio and rate reasoning to solve real-world and mathematical problems. • **SL.6.1** Engage effectively in a range of collaborative discussions with diverse partners on *grade 6 topics, texts, and issues*, building on others' ideas and expressing their own clearly. • **NHMO.8.5** Recognize and respond to the people, places, and natural elements in their community.	**Weather and Climate** **MS-ESS3-5** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. **Matter and Energy in Organisms and Ecosystems** **MS.LS2-4** Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.	• Blue line data and projected sea level rise • Rate of sea level rise and proportional rate of warming. • Rates of sea level rise and rise in mean global air temperatures • Investigating patterns of local climate and sea level changes

Assessments

Students:

- Describe the ratio relationship they used to calculate a new beach profile based on projected rise in sea level.
- Collect and summarize data of ocean conditions.
- Write a reflection about the local consequences of global carbon emissions, including sea level rise, erosion of beaches, increased threat from tsunamis and storms, and changing pH and water temperatures.

Assessment Adjustments for NGSS

Students:

- Generate questions to clarify evidence they have gathered at this point in the unit.
- Begin constructing an argument, citing evidence gathered in the field and in readings, to support claims that changes to climate are affecting coral reefs and sea level in Hawai'i.

Class Periods: 2 - 3 plus field study

Student Pages

- Student Readings 3 and 4
- Student Data Sheets 1 - 3
- Vocabulary Practice 3

4: Hō‘ailona (Signs of Nature)

How are changes in local weather, ocean conditions, and in plants and animals clues to climate change?

Standards	Benchmarks	Next Generation Science Standards (NGSS)	Key Concepts
Science 1: The Scientific Process - Scientific Inquiry **Science 2: Nature of Science** - Science, Technology and Society **Language Arts: Writing -** Production and Distribution of Writing (W) **‘Ike Pilina - Relationship Pathway** **‘Ike Honua - Sense of Place Pathway**	• **SC.6.1.2** Use appropriate tools, equipment and techniques safely to collect, display, and analyze data. • **SC.6.2.1** Explain how technology has an impact on society and science. • **W.6.6** Use technology, including the Internet, to produce and publish writing as well as to interact and collaborate with others. • **NHMO.1.3** Interact with kūpuna in a loving and respectful way. • **NHMO.8.1** Be keen observers of their natural environment.	**Matter and Energy in Organisms and Ecosystems** **MS.LS2-4** Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.	• Changing weather and ocean conditions - clues to local climate and sea level change. • Changes in plants and animals - clues to changing ocean conditions • Protocols for conducting interviews of kūpuna and others

Assessments

Students:

- Collaborate with a group to collect data about local ocean, shoreline, or weather conditions.
- Complete an interview with kūpuna, fisher or other community member familiar with ocean or weather conditions to record observed changes.
- Write a team letter to students in Alaska to respond to the observations of their elders and to share local concerns and images about climate change in Hawai‘i.

Notes

Assessment Adjustments for NGSS

- Have students continue constructing an argument, citing evidence gathered in the field and in readings to support claims that changes to climate are affecting coral reefs and sea level in Hawai‘i.
- Provide feedback on writing and have students revise to improve their work and express their deepening understanding.

Class Periods: 3 - 4

Student Pages

- Student Reading 5
- Learning Logs 5 and 6
- Interview Forms

5: Energized!

How do we change the way we harness and use energy to reduce our carbon footprint in Hawai'i?

Standards	Benchmarks	Next Generation Science Standards (NGSS)	Key Concepts
Science 2: Nature of Science - Science, Technology and Society **Science 6: Nature of Matter and Energy** - Energy and its Transformation **Language Arts: Writing -** Research to Build and Present Knowledge (W) **Language Arts: Speaking and Listening** - Comprehension and Collaboration (SL) **'Ike Honua - Sense of Place Pathway**	• **SC.6.2.2** Explain how the needs of society have influenced the development and use of technologies. • **SC.6.6.3** Explain how energy can change forms and is conserved. • **W.6.8** Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources. • **W.6.9** Draw evidence from literary or informational texts to support analysis, reflection, and research. • **SL.6.1** Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher led) with diverse partners on *grade 6 topics, texts, and issues*, building on others' ideas and expressing their own clearly. • **NHMO.8.14** Participate in conservation and recycling practices and activities. • **NHMO.8.19** Identify and utilize appropriate forms of technology for improving the quality of life in the community.	**Human Impacts** **MS-ESS3-4** Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.	• Shifting reliance on carbon-based fuels to renewable sources • Calculating carbon footprints • Lifestyles changes to reduce energy use and impact climate change

Assessments

Students:

- Calculate their carbon footprints and take action to reduce their energy consumption and carbon output.
- Collaborate with others to conduct research into a form of alternative energy for Hawai'i and explain how it transfers and conserves energy compared to fossil fuels.

Assessment Adjustments for NGSS

Students:

- Work in pairs to study CO_2 emissions per-capita and per country graphs and use the data to construct an argument about human population growth, use of fossil fuels, and impact on Earth's atmosphere and oceans.

Class Periods: 2 with additional group time to work independently on projects

Student Pages

- Learning Logs 7 - 10
- Getting Started - Student References

6: Culminating Activity: Rising Seas?

How do we know if Hawai'i's sea level is rising due to global climate change and what can we do about it?

Standards	Benchmarks	Next Generation Science Standards (NGSS)	Key Concepts
Science 2: Nature of Science - Science, Technology and Society **Science 6: Nature of Matter and Energy** - Energy and its Transformation **Language Arts: Writing** - Text Types and Purposes (W) **Language Arts: Speaking and Listening** - Presentation of Knowledge and Ideas (SL) **'Ike Honua - Sense of Place Pathway** **Ike Ho'okō - Applied Achievement Pathway**	• **SC.6.2.1** Explain how technology has an impact on society and science. • **SC.6.6.3** Explain how energy can change forms and is conserved. • **W.6.2** Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. • **SL.6.4** Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation. • **SL.6.5** Include multimedia components (e.g., graphics, images, music, sound) and visual displays in presentations to clarify information. • **NHMO.8.14** Participate in conservation and recycling practices and activities. • **NHMO.7.1** Know what their kuleana is in various situations.	• **MS-ESS3-4 Human Impacts** Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.	• Needs of society and ever-changing technologies • Reducing our carbon footprints to slow the process of climate change and sea level rise • Qualities of effective presentations - logical sequence, relevant information, summaries and conclusions • Effective visual displays - link to and help explain thinking and engage audience in ideas

Assessments

Students:

- Write a paper to answer the unit essential question using data collected and facts gathered in an organized manner, using a logical sequence of ideas and relevant, descriptive details.
- Collaborate in teams to research and report on:
  1. a clue to climate change and rising sea level
  2. a form of alternative energy for Hawai'i; how it transfers and conserves energy and how it compares to fossil fuels.
- Add effective visual displays to their presentations to enhance the development of main ideas.

Assessment Adjustments for NGSS

- Construct an argument, supported by evidence for the benefits of using alternative energy in place of fossil fuels to reduce human impact on Earth's atmosphere and oceans by reducing CO_2 emissions.

Class Periods: 3 plus hō'ike (student exhibit)

Student Pages

- Self Assessment - Teamwork
- Project Rubrics
- Presentation Planner

NAME_____**DATE**_____ **POINTS**_____

Essential Question: How do we know if Hawai'i's sea level is rising due to global climate change and what can we do about it?

Standards	Below Points_____	Approaching Points_____	Meets Points_____	Exceeds Points_____
Language Arts - Writing **W.6.2** **GLO 3 - Complex Thinker**	Little or no evidence of: • selecting relevant content • analyzing it to answer the unit essential question	• Selected some relevant content • Partially answered the unit essential question	• Selected relevant content • Analyzed the topic to answer the unit essential question	• In-depth analysis of the topic and selection of relevant content • Thoughtful, detailed answer to the unit essential question
Language Arts - Writing **W.6.2**	• Writing unorganized and only minimally informative • And/or lacked a clear introduction and conclusion	• Somewhat informative and organized writing • Lacked relevant detail and a clear introduction and conclusion	• Informative, organized writing • Good introduction and conclusion	• Very informative writing; used relevant details in an organized manner • Excellent introduction and conclusion
Science **SC.6.2.1** **NHMO 7.1** **Know your kuleana**	• No connections between evidence for climate change in Hawai'i and sea level rise • Did not explain how to reduce your carbon footprint and slow the process of climate change	• Presented minimal evidence for rising sea level due to climate change in Hawai'i • Explained at least one way to reduce your carbon footprint and slow the process of climate change	• Presented evidence for rising sea level due to climate change in Hawai'i • Explained how you could reduce your carbon footprint and slow the process of climate change	• Presented detailed evidence for rising sea level due to climate change in Hawai'i • Explained how you are reducing your carbon footprint to slow the process of climate change

Language Arts References	• Included either no references, or the references provided were not in correct format	• At least one reference was in the correct format	• Most references were in the correct format	• All references were in the correct format

NGSS Earth and Space Science MS-ESS3-4	• Did not connect data collected in this unit on human use of fossil fuels and rising sea level in Hawai‘i	• Did not make a clear connection between data collected in this unit on human use of fossil fuels and rising sea level in Hawai‘i	• Constructed an argument supported by data collected in this unit to explain how human use of fossil fuels is linked to rising sea level in Hawai‘i	• Constructed a cohesive argument that clearly explained how data collected in this unit relates to human use of fossil fuels and rising sea level in Hawai‘i

NAMES_____**DATE**_____ **POINTS**_____

Essential Question: How do we know if Hawai'i's sea level is rising due to global climate change and what can we do about it?

Standards	Below Points_____	Approaching Points_____	Meets Points_____	Exceeds Points_____
Language Arts -Speaking and Listening **SL.6.4** **GLO 3 - Complex Thinker**	• Did not present claims and ideas logically, in sequence • Did not use pertinent facts and details to make the main points	• Presented claims and ideas, but needed more: • logical thinking so the audience could follow • pertinent facts and details to make main points	• Presented claims and ideas logically, in sequence • Used pertinent facts and details to make the team's main points	• Presented claims and ideas logically, in sequence • Used pertinent facts and details to make a strong case for team's main points
Language Arts -Speaking and Listening **SL.6.4** **GLO 5 - Effective Communicator**	• Rarely used appropriate eye contact, adequate volume, or clear pronunciation	• Sometimes used appropriate eye contact, adequate volume, and clear pronunciation	• Used appropriate eye contact, adequate volume, and clear pronunciation	• Used appropriate eye contact, adequate volume, and clear pronunciation • Team was animated and engaged the audience
Language Arts -Speaking and Listening **SL.6.5** (graphics, images, music, or sound and visual displays)	• Did not use multimedia components and/or visual displays to present and clarify information	• Use of multimedia components and/or visual displays did not clearly connect to content or clarify information	• Good use of multimedia components and/or visual displays to present and clarify information	• Excellent use of multimedia components and/or visual displays to present and clarify information and engage the audience

Science **SC.6.2.1** **NHMO 7.1** **Know your kuleana**	• Did not connect data collected in this unit on climate change to rising sea level in Hawai‘i	• Did not make a clear connection between data collected in this unit on climate change and rising sea level in Hawai‘i	• Used data collected in this unit to explain one clue to climate change and rising sea level in Hawai‘i	• Clearly explained how data collected in this unit relates to climate change and rising sea level in Hawai‘i
Science **SC.6.6.3**	• Presented a potential form of alternative energy for Hawai‘i • Did not explain how the alternative energy transfers and conserves energy, or how it compares to our use of fossil fuels	• Presented a potential form of alternative energy for Hawai‘i, but did not clearly explain how it transfers and conserves energy • Comparison of the alternative energy to our use of fossil fuels was lacking or unclear	• Explained how a potential form of alternative energy for Hawai‘i transfers and conserves energy • Compared the alternative energy to our use of fossil fuels	• Explained, with detailed graphics, how a potential form of alternative energy for Hawai‘i transfers and conserves energy • Provided a detailed comparison of the alternative energy to our use of fossil fuels
NGSS **Earth and Space Science** **MS-ESS3-4**	• Did not connect data collected in this unit on human use of fossil fuels and rising sea level in Hawai‘i	• Did not make a clear connection between data collected in this unit on human use of fossil fuels and rising sea level in Hawai‘i	• Constructed an argument supported by data collected in this unit to explain how human use of fossil fuels is linked to rising sea level in Hawai‘i	• Constructed a cohesive argument that clearly explained how data collected in this unit relates to human use of fossil fuels and rising sea level in Hawai‘i

Learning Log

Kai E‘e – Mounting Seas
Climate Change

Name: _____

School: _____

Date Started: _____

Date Completed: _____

UNIT ASSESSMENT OVERVIEW

UNIT ESSENTIAL QUESTION: *How do we know if Hawai'i's sea level is rising due to global climate change and what can we do about it?*

NĀ HONUA MAULI OLA (NHMO) – HAWAIIAN CULTURAL PATHWAYS

'Ike Pilina - Relationship Pathway

- Interact with kūpuna in a loving and respectful way that demonstrates an appreciation of their role as culture bearers and educators in the community.

'Ike Mauli Lāhui: Cultural Identity Pathway

- Demonstrate culturally appropriate behavior and traditional knowledge skills.

'Ike Na'auao - Intellectual Pathway

- Continue to develop personal communication, participation and collaboration skills.

'Ike Ho'okō - Applied Achievement Pathway

- Demonstrate the use of acquired knowledge through application.

'Ike Honua - Sense of Place Pathway

- Be keen observers of their natural environment.
- Participate in conservation and recycling practices and activities.
- Identify and utilize appropriate forms of technology for improving the quality of life in their community.
- Recognize and respond to the people, places, and natural elements in their community.

- **Values:** kuleana (responsibility) and laulima (working together)

LESSONS, STANDARDS, GLOS, AND LEARNING LOGS	COMPLETED ✓
1. Heating Up! - Science 2 and 6; Language Arts - Writing 9 Learning Logs 1 - 2	
2. More Melting - Science 1 and 6 Learning Logs 3 - 4	
3. Carbon Consequences - Science 1 and 2; Math - Ratio and Proportion 1; Language Arts 6 - Speaking and Listening 1 Student Data Sheets 1 - 3	
4. Hō'ailoana (Signs in Nature) - Science 1 and 2; Language Arts - Writing 6 Learning Logs 5 - 6	
5. Energized! - Science 6; Language Arts: Writing 8 and 9; Speaking and Listening 1 Learning Logs 7 - 10	
6. Kai E'e: Mounting Seas - Science 2 and 6; Language Arts - Writing 2; Speaking and Listening 4 and 5; GLO 3 and 5 Self-Assessment Rubric and Presentation Planner	

GROUP PROJECT DUE DATE:_____

Work with a team to answer the unit essential question: *How do we know if Hawai'i's sea level is rising due to global climate change and what can we do about it?*

Your team will need to report on two topics:

1) a clue to climate change and rising sea level, based on what we discover in this unit

2) a form of alternative energy for Hawai'i; how it transfers and conserves energy and how it compares to fossil fuels.

For each of these topics, your team will need to:

- Read materials and cite references according to a format agreed upon in class.
- Report on data collected in the unit.
- Work with other teams to share data and draw conclusions.
- Develop a two-part presentation to present your findings:
  - Climate change: a class computer presentation where each team contributes 2 or 3 slides. Presentations should include photographs and data from your field study and video, audio, or quotes from community interviews.
  - Alternative energy: each team chooses a method to present its findings. These could include demonstrations, models, poster boards, videos, or public service announcements to others in the community.

INDIVIDUAL PROJECT DUE DATE:_____

Your work on the team project will help you to write your own paper to answer the unit essential question and summarize what you have learned in this unit.

- Your paper should be at least two pages in length and should include:
  - A brief description of climate change
  - Evidence for rising sea level due to climate change in Hawai'i
  - How rising sea level would impact your community
  - How your actions can help to reduce your carbon footprint and slow the process of climate change and sea level rise

Be sure to write an introduction and conclusion and cite any references. We will review a rubric to help guide your work.

Heating Up!

How are human activities contributing to a warming planet?

Activity at a Glance

Students begin the unit with an oli (chant) to set the tone of respect and reverence for the elements. They examine data from Mauna Loa and conduct demonstrations to explore the role of greenhouse gases in warming the planet.

Key Concepts

- The Hawaiian relationship to ʻāina, including reverence for all natural elements, is a perspective that can guide us to develop a meaningful connection to the natural world.
- Heat from the Sun is transferred through space to the Earth by radiation. The Earth reradiates some of the Sun's energy back to space. Some of the re-radiated energy is trapped like the heat in a greenhouse by atmospheric gases, which include carbon dioxide and methane.
- Greenhouse gases, such as carbon dioxide, are increasing in the atmosphere due to human activities, such as burning fossil fuels and clearing forests.
- Carbon changes both physical and chemical forms as it cycles between the soil, living things, the atmosphere and the oceans.

Skills

Observing, inferring, graphing, analyzing, writing

Assessment

Students:

- Complete a diagram that illustrates how heat energy re-radiates from Earth back into space and how greenhouse gases absorb heat and warm the planet.
- Illustrate and explain how carbon is released and absorbed as it moves and changes form in a balanced and unbalanced carbon cycle.
- Write a reflection about their personal connection to natural elements and how the needs of society today are impacting the planet.

Hawai'i State Standard Benchmarks

Science 2: Nature of Science - Science, Technology and Society

- **SC.6.2.1** Explain how technology has an impact on society and science.

Science 6: Nature of Matter and Energy - Energy and its Transformation

- **SC.6.6.1** Compare how heat energy can be transferred through conduction, convection, and *radiation*.
- **SC.6.6.5** Explain how matter can change physical or chemical forms, but the total amount of matter remains constant.

Common Core Standards

Language Arts: Writing - Research to Build and Present Knowledge

- **W.6.9** Draw evidence from literary or informational texts to support analysis, reflection, and research.

Nā Honua Mauli Ola

ʻIke Mauli Lāhui: Cultural Identity Pathway

- **NHMO.3.4** Demonstrate culturally appropriate behavior and traditional knowledge skills.

Suggested Timeframe

Five 45-50-minute class periods

Day 1: Introduction, unit pre-assessment and K-W-L chart
Day 2: The Greenhouse Effect - animation and experiment
Day 3: Student Reading 1 in class reading and review
Day 4: The Carbon Cycle
Day 5: Wrap up K-W-L and Unit Student Assessment Overview

Materials

Provided

- Oli (*Hiki Mai Ka Lā* is provided on CD)
- Unit Pre-assessment (provided in Unit Introduction
- Student Reading 1: Greenhouse Effect and Carbon Cycle
- Learning Log 1: Greenhouse Effect
- Learning Log 2: Carbon Cycle
- Vocabulary Practice 1
- Student Assessment Overview (provided in Unit Introduction)
- Teaching Aid: Greenhouse Effect
- Student Resources (reference page for students)

For You to Provide

- Trowel
- Greenhouse Effect Materials - For each team of 4 - 5 students:
  - 2 thermometers
  - 2 clear containers (same-size trays or boxes)
  - plastic cling-wrap
- Computers for student research

Getting Ready

- ✓ Review the Student Assessment Overview and Unit Pre/Post-assessment provided in the Unit Introduction. Copy these documents for each student.
- ✓ Make a copy of Student Reading 1, Learning Logs 1 - 2 and Vocabulary Practice 1 for each student.
- ✓ Prepare to project the CO_2 and temperature graphs provided in the Student Reading and the Greenhouse Effect Teaching Aid.
- ✓ Preview and prepare to share animations and information from the following websites:
  - ✓ Environmental Protection Agency: the greenhouse effect and carbon cycle videos from the Website: http://www.epa.gov/climatechange/kids/basics/today/greenhouse-effect.html
  - ✓ http://www.epa.gov/climatechange/kids/basics/today/carbon-dioxide.html.
  - ✓ http://www.epa.gov/climatechange/kids/scientists/proof.html Has an excellent graph on CO_2 in the atmosphere over past 650,000 years.
  - ✓ Geophysics Institute, University of Alaska Fairbanks: Interactive Multimedia 1000 Years of Change: http://arcticclimatemodeling.org/Movies/data_analysis_dvd_sample.html

Vocabulary

Carbon: an element that is abundant in many forms and found in the atmosphere, soil, oceans, and living things

Carbon cycle: the cycle of carbon between the atmosphere, oceans, living things, and crustal rocks; largest repository of carbon on the planet is actually carbonate rocks

Carbon dioxide: a gas formed during respiration, combustion and decomposition of living things

Climate: the average weather conditions in a location or region over time

Climate change: significant changes in temperature, precipitation, wind and other weather patterns over an extended period of time

Fossil fuel: coal, oil, and natural gas derived from the remains of prehistoric plants and animals

Greenhouse effect: the process of gases in the atmosphere absorbing heat radiating from the Earth

Greenhouse gases: gases in the atmosphere including carbon dioxide, water vapor, methane, and nitrous oxide

Mālama ʻāina: caring for the Earth

Radiation: in this context, the movement of energy in the form of waves

Weather: the conditions in the atmosphere at a particular time and place, including temperature, wind, and humidity

Teacher Background Information

The unit begins with the oli (chant), *Hiki Mai Ka Lā*. This chant and its motions were shared with the Windward Oʻahu kūpuna (elders) by Anakala Kimo Awai of Hilo along with the Hilo district's kūpuna. It is both a chant of welcome to the morning Sun in the sky as well as a request for inspiration from ke akua, the creation, or our ancestors.

As we look at the growing body of evidence for a warming planet and the changes this warming is wreaking on natural systems, it behooves us to look to the past, to honor the elements and to reconnect with ʻāina (land, sea, heavens) with more reverence and respect for that which provides for us.

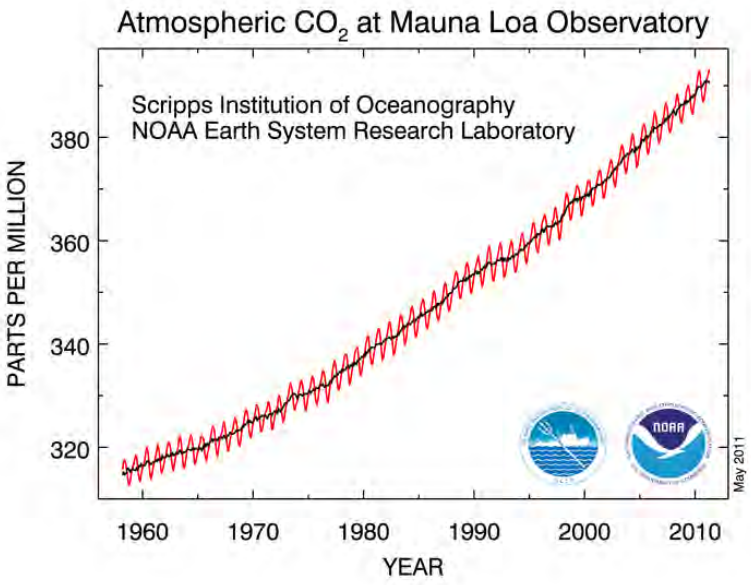
> "Some scientific conclusions have been so thoroughly examined and tested, and supported by so many independent observations and results, that their likelihood of being found wrong is vanishingly small. Such conclusions are then regarded as **settled facts**. This is the case for the conclusions that the Earth system is warming and that much of this warming is very likely due to human activities…strong evidence on climate change underscores the need for actions to reduce emissions and begin adapting to impacts."
>
> *America's Climate Choices, U.S. National Academy of Science, National Research Council, 2011*

The Greenhouse Effect

Heat reaches the Earth in the form of shortwave radiation from the Sun. Some of the Sun's energy is absorbed by the Earth and some is re-radiated as longer wavelengths out to space. The "greenhouse gases" are gases like carbon dioxide, water vapor, and methane that keep our planet habitable by absorbing energy re-radiated from the Earth's surface. Like the roof of a greenhouse, the greenhouse gases absorb and effectively trap some of this re-radiated energy, deflecting it back to Earth, warming the planet and making it habitable for life as we know it. (See diagram on Teaching Aid provided with this lesson.)

Greenhouse Gases

Greenhouse gases such as carbon dioxide, water vapor, methane and nitrous oxide occur naturally in the atmosphere. The increase in these gases due to burning of fossil fuels and deforestation results in more heat being trapped in the atmosphere. Other synthetic greenhouse gases produced by humans, such as chlorofluorocarbons (CFCs), add to the greenhouse effect. For more information on greenhouse gases, see the NOAA website: http://www.ncdc.noaa.gov/oa/climate/gases.html.



Carbon Dioxide

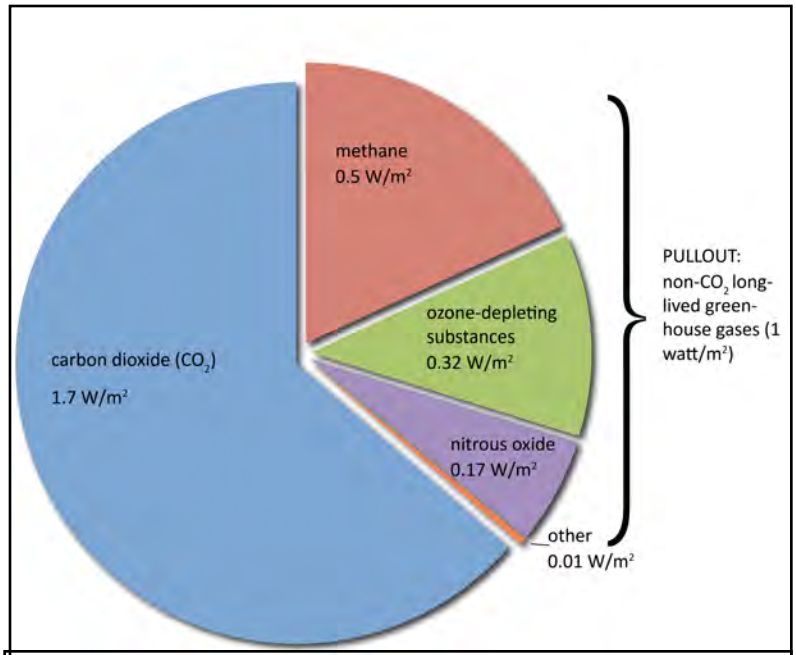
What happens when we increase greenhouse gases in the atmosphere? On top of Mauna Loa on Hawai‘i Island, scientists have been collecting data of carbon dioxide in our atmosphere since 1958. The data shows that the amount of CO_2 in the atmosphere has increased from 316 ppm (parts per million) to approximately 389 ppm in September 2011. Recent trends are even higher; in March 2013, the CO_2 level in the atmosphere reached 397 ppm. (See: http://www.esrl.noaa.gov/gmd/ccgg/trends/ for updates on CO_2 in the atmosphere.)

The red line of the graph shows the seasonal variation as the increase of photosynthesis in warmer months in the northern hemisphere takes more carbon dioxide out of the atmosphere. The curve of the line on the graph, often referred to as the “Keeling curve,” is named for Dr. Charles Keeling, the meteorologist who led the team collecting this data on Mauna Loa.

The Student Reading included with this lesson includes this graph along with a graph showing variation in global temperature over the past 130 years. Both graphs depict upward trends with changes accelerating at approximately the same time in the decade between 1960 and 1970. As we can see from Keeling’s curve, CO_2 is rising; it is the major contributor to climate change today (Karl et al. 2009). This is partly because CO_2 is so long-lived in the atmosphere. Over half of the CO_2 produced by human activity since the beginning of the Industrial Revolution is still in the atmosphere (Flannery, 2005). Burning fossil fuels is the major cause of this CO_2 rise, contributing to the warming of the planet. The second leading cause of CO_2 rise is from deforestation, with an estimated 20% to 23% of yearly CO_2 emissions coming from burning and destroying forests (Gore 2009).

Methane

Methane, another greenhouse gas, is believed to be the second most powerful contributor to climate change. Even though it is more than 20 times as effective as CO_2 in trapping heat in the atmosphere, the amount released into the atmosphere is much less than CO_2, so its impact on climate change is less (Gore 2009). Methane is released through rice cultivation, melting permafrost, livestock, and decaying wastes from landfills. Slightly more than half of the methane released into the atmosphere comes from the tropics (Amazon river basin and the Congo basin). Approximately one-third of the methane comes from China and SE Asia rice paddies, and about 2% comes from the Arctic permafrost (Adam 2010). Although the Arctic source is relatively small, it is a major concern. As the Arctic warms, previously frozen "permafrost" is melting and releasing methane in much larger quantities than scientists had anticipated. Methane released from the Arctic increased by 31% from 2003-07 (Adam 2010).



The direct warming influence of all long-lived greenhouse gases in the atmosphere today attributable to human activities. CO2's warming influence of 1.7 watts/square meter is equivalent to heat from nearly 9 trillion 100-watt incandescent light bulbs placed across Earth's surface. The combined influence of the other gases is equivalent to the heat from about 5 trillion bulbs. "Other" includes a few very long-lived chemicals that can exert a climate influence for millennia. Source: Courtesy of NOAA.

The Carbon Cycle

> "The annual average human-induced flows of CO_2 - 6.3 gigatons (Gt) from fossil-fuel combustion and 1.6 Gt from deforestation in the 1990s - are a small fraction of total CO_2 flows. However, these flows are resulting in increased carbon in the ocean and atmospheric reservoirs."
>
> --Pew Center Global Climate Change

As students will see with the animation suggested for use with this lesson, when the carbon cycle is in balance, the carbon going into the atmosphere is in equilibrium with the carbon taken up by the ocean, living things, and the soil. Carbon is released through respiration and decomposition of living things as well as through wildfires, volcanoes and burning of fossil fuels. Carbon is absorbed by plants through the process of photosynthesis, it moves into animals that eat the

carbohydrates the plants store. Animals respire and release CO_2 to the atmosphere. Much of the carbon in the carbon cycle resides in oceans, where 20 times more carbon dioxide is dissolved in seawater than is found in the soil and in living things on land (JGOFS 1990). The role of oceans in the carbon cycle and climate change will be explored in the next lesson.

When we burn fossil fuels and forest lands we interfere with the natural carbon cycle by moving carbon from a solid, stored state to a gaseous state. In this lesson, students are introduced to the greenhouse effect and the carbon cycle. The Environmental Protection Agency has excellent animations of both of these concepts available online. See the Getting Ready section above to preview the animations and prepare to share them with your students.

TEACHING SUGGESTIONS

Introducing the Unit

1. **Introduce the oli provided with this lesson (note: *Hiki Mai Ka Lā* is provided on CD).**
   - Explain that the oli are both a chant of welcome to the morning Sun in the sky as well as a request for inspiration from ke akua, the creation, or Hawaiian ancestors.
   - Discuss the oli with students.
     - What does the chant reveal about the Hawaiian relationship to Lā (the Sun)?
     - Why do we look to ke akua (deities) or ancestors for inspiration?
     - How does having reverence for natural elements guide our actions?
     - In the Kānehoalani chant, what legend is referred to in the reference to the kapa-beating?
     - How does the Sun transmit energy to the Earth (shortwave radiation, much of which easily passes through our atmosphere)
     - What role does the atmosphere play in making the Earth hospitable? (absorbs heat, increasing and sustaining the temperature of the planet)
   - Play the oli again and have the students chant along with it.
   - Ask students to keep this mālama ʻāina perspective of reverence for the natural world in mind as they explore this new unit on climate change and ways that all of us can help to restore balance on the planet.

2. UNIT PRE-ASSESSMENT: Post the essential question for the unit.

Essential Question: *How do we know if Hawai'i's sea level is rising due to global climate change and what can we do about it?*

- Distribute the unit pre-assessment and ask students to write their names, the name of the school and the date at the top of the page.
- Explain that some scientists are predicting a one meter rise in sea level in Hawai'i by the turn of the century. Explain that during the course of the unit, students will be piecing together clues to climate change and sea level rise and sharing what they learn with others. To get started, ask them to answer the questions on the pre-assessment to the best of their ability. Explain that they will not be graded on the assessment, but it will help to show what they may already know about climate change and sea level rise.
- Collect student responses and save them for comparison with post-assessment at the end of the unit.

3. Set up a K-W-L chart to discuss what students know and want to know about climate change and sea level rise.

- Have students sit with a partner and give each pair two slips of recycled paper.
- Ask them to write something they know and something they would like to know about climate change, sea level rise, or alternative energy. Suggest that they consider some of the questions on the pre-assessment as they consider this.
- Have students share and post what they know under the K on the chart in front of the room and what the would like to know under the W.
- Discuss their ideas and questions.
- Clarify the difference between climate and weather (see Vocabulary) and explain that climate change represents significant changes in temperature, precipitation, wind and other weather patterns over an extended period of time.
- Distribute the **Vocabulary Practice 1** sheet to each student and ask them to begin filling in the definitions as they learn them.

Part 1: The Greenhouse Effect

4. Show the online animation of the greenhouse effect to students. Go to: http://www.epa.gov/climatechange/kids/basics/today/greenhouse-effect.html

- Since many island students may be unfamiliar with greenhouses, introduce the video by comparing how the temperature warms up in a greenhouse to the temperature warming inside a car that is closed up and sitting in the sun.
- After watching the animation, use the **Greenhouse Effect Teaching Aid** provided with this lesson and discuss the process with students.
  - How is heat energy transferred in the process of the greenhouse effect? How is radiation important in this effect? (Shortwave radiation from the Sun warms the Earth, which re-radiates longer wavelength heat energy into space, some of which is absorbed by greenhouse gases, and reradiated back to Earth).
  - How does the greenhouse effect make our planet habitable? (Without this warming effect, the planet would be, on average, 60 degrees F colder.)
  - What kinds of human activities are increasing greenhouse gases in the atmosphere? (Combustion of fossil fuels, burning of forests)
  - Why is the increase of greenhouse gases a problem? (Climate change - the focus of this unit)

5. Divide the class into teams of four or five students and give each team a set of the greenhouse effect materials.

- Challenge each team to use the materials: (2 thermometers, 2 clear containers, plastic cling-wrap, trowel) to design a way to demonstrate the greenhouse effect. As an additional challenge, see which team can record the highest temperature.
- Set a time limit (approximately 15 minutes) for the groups to come up with a demonstration, record temperature readings, and share it with the rest of the class.
- Take students outside to set up their demonstrations in the sun. If they want to add soil to their trays, show them where they can dig some soil with a trowel on the school grounds.
- Circulate and help students as needed, but let them try to work out their own demonstrations. Discuss the importance of setting up two identical trays with only the variable changing (the plastic wrap that represents the greenhouse gases). [Both trays should be set up in the sun with a thermometer inside, preferably propped up to catch the sun's rays. Adding soil to both trays will provide a dark color to absorb heat. One tray should have a layer of clear plastic wrap or two secured, and the other tray should be set up in the same way with no cover; the cover simulates the "blanket" of greenhouse gases.]

Remind students to laulima (cooperate) on the greenhouse effect challenge and be mindful of everyone's input and ideas.

6. Ask teams to share their demonstrations and findings.

- Reinforce the concept of energy transfer by radiation.
- Discuss the results.
  - Which team had the hottest temperatures? Why?
  - What was the largest difference in temperature between the two trays in any one demonstration?
  - How was the plastic cling-wrap used? Why?
  - What did the plastic wrap represent in the models? How is this a shortcoming of this model? (*Emphasize that greenhouse gases are not like a solid plastic cover, but a layer of heat-trapping gases surrounding the Earth*.)
  - Did it make a difference in temperature if double layers of plastic wrap were placed over one container? Did it make a difference if soil was added?
  - Did it make a difference if the trays were placed on an angle facing the sun? How?
  - What might happen if we put the trays in a dark area to simulate night? Would they cool off at the same rate? Why or why not? (You may want to try this as an extended activity.)

7. Have students work in small groups to read Student Reading 1.

- Ask groups to read the material together and highlight the key points in the Reading.
- Have groups share their understanding of the key points and clarify as needed.
- Review **Learning Log 1** and ask students to complete it as homework.
- Discus student responses to the Learning Log questions.

NGSS:

Have students include explanatory text describing their models of thermal energy transfer and how this relates to the greenhouse effect.

Part 2: The Carbon Cycle

8. Activate prior knowledge with a discussion of the water cycle.

- Give students one minute to draw a picture of the water cycle and label it. Challenge them to show evaporation, condensation, precipitation, transpiration, and run-off of water.
- Discuss their drawings. Ask them to describe how the water changes as it moves through the cycle. (water - liquid, water vapor - gas, and ice - solid)

9. **Introduce the carbon cycle. View the online animation, either as a class or with students working in pairs. Go to:** http://www.epa.gov/climatechange/kids/basics/today/greenhouse-effect.html
   - Ask students to explain how the carbon cycle is different from the water cycle.
     - The water molecules change their physical state, but remain H_20 in the water cycle. Carbon atoms combine with other atoms to form new molecules as carbon moves through the carbon cycle. So there are both physical and chemical changes in the carbon cycle.)
   - Distribute **Learning Log 2** and ask students to take notes from the animation to answer the questions.
   - Discuss students' reactions to the animation.
     - What kinds of human activities are adding CO_2 to the atmosphere?
     - How does this relate to the greenhouse effect?

10. **Have students complete the arrow diagrams on Learning Log 2 and discuss their responses.**
     - Which processes result in carbon being absorbed? (ocean and land plants - photosynthesis; animals - feeding; fossil fuels - deposits)
     - Which processes result in carbon being released? (plants and animals - respiration; volcanoes - eruptions; plants and animals die - decomposition; wildfires; burning fossil fuels)
     - How does matter (carbon) change physical and chemical forms in the carbon cycle? For example, carbon atoms combine with oxygen to form carbon dioxide (gas).
   - Ask students to work with a partner to explain how carbon atoms combine with other atoms to form new molecules: a) in the process of photosynthesis and b) in the process of burning fossil fuels.
   - Have students explain their answers.

NGSS:

Have students ask questions to clarify evidence in their reflections.

Add explanatory text to their illustrations of the carbon cycle to describe the cycling of matter and flow of energy.

Answers: a) Plants take in CO_2 (gas) and using energy from the sun combine the CO_2 with water H_2O to create simple sugars or carbohydrates (solids) - $C_6H_{12}O_6$. b) Fossil fuels (solids - hydrocarbons) are burned and release CO_2 (gas).

Part 3: Summary and Student Assessment Overview

11. **Revisit the K-W-L chart.**
   - Ask students to summarize what they have learned and list these summaries under the L on the chart.
   - Have all questions listed under the W been answered? Have new questions been generated? Ask students to work individually or in teams to conduct some research to answer questions. See the **Student**

Resources page which lists websites and books for students (last page of student sheets).
- Project the References for Students provided with this lesson to help students get started in answering their questions.
- Ask students to complete the **Vocabulary Practice 1** page. Review their definitions and begin a **Word Wall** for the unit with vocabulary words listed and defined.

12. Distribute and review the Student Assessment Overview.
- Point out the chart for keeping track of Learning Log pages that will form students' climate change logs.
- Introduce the culminating activities and explain that the projects will be an expression of what students will discover in the unit.
- Explain that research to answer student questions will be on-going through the course of the unit.

Extending the Learning

- Challenge students to conduct a greenhouse gases experiment making CO_2 with vinegar and baking soda. See "Greenhouse Gases Exposed" online at: http://cleanet.org/resources/42746.html.

- View the Kaiakahihali'i chant and story on the *Kai E'e* Project website: http://discovertsunamis.org with students. Discuss the significance of this story in relation to the interaction of land and sea and the Hawaiian deities associated with the sea.

- Have students conduct research into air temperatures in Hawai'i over the past few decades and graph the results. Online temperature data is available at: http://data.giss.nasa.gov/csci/stations/. Click on Honolulu on the map and then select the station nearest you. (Data is available for Līhue, Moloka'i, Lāna'i City, Lahaina, Hāna and Hilo.) The data appears as a sheet of numbers, so you may want to suggest that students extract data by decade. Also note that where data is missing, the numbers are recorded as 999.99, so have students pull out data starting with 1930.

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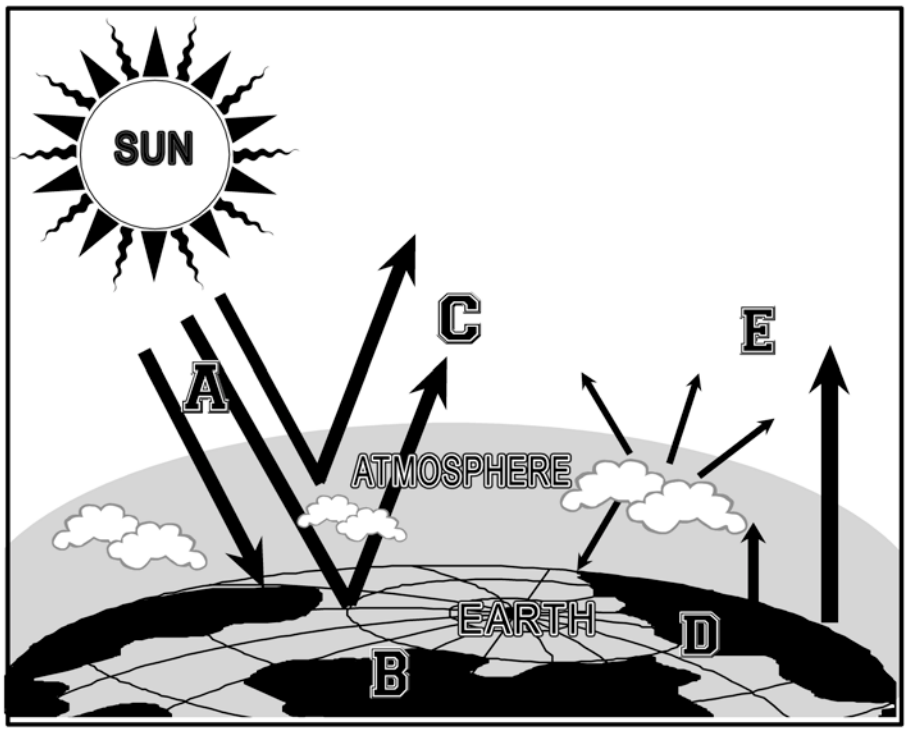
TEACHING AID

THE GREENHOUSE EFFECT



A. Solar radiation passes freely through the atmosphere.

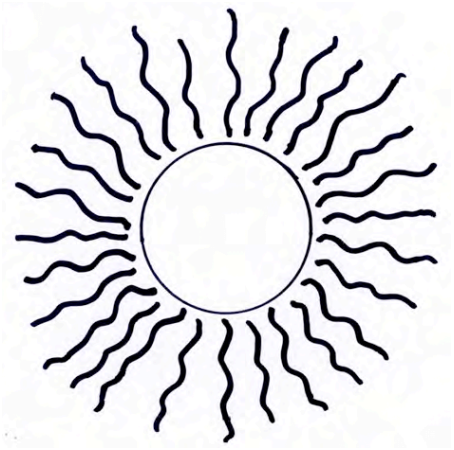
B. Most of this radiation (about 70%) is absorbed by the Earth and warms the planet.

C. Some of the solar radiation (about 30%) is reflected back to space from clouds and from snow and ice on Earth.

D. The Earth emits infrared radiation in the form of heat waves.

E. Greenhouse gases like carbon dioxide, water vapor, and methane absorb some of the energy re-radiated from the Earth's surface and re-emit it in all directions. Some of the energy goes back to Earth, which warms the planet and the lower atmosphere.

Oli



Hiki Mai Ka Lā

From Pele and Hi‘iaka - A Myth from Hawai‘i
by Nathaniel B. Emerson (1915)

Hiki mai, hiki mai ka lā *Aloha wale, ka lā e kau nei* *Aia malalo o Kawaihoa* *A ka lalo o Kaua‘i* *O Lehua*	Here it comes, here comes the Sun How I love the Sun in the sky There below is Kawaihoa On the incline of Kaua‘i is Lehua

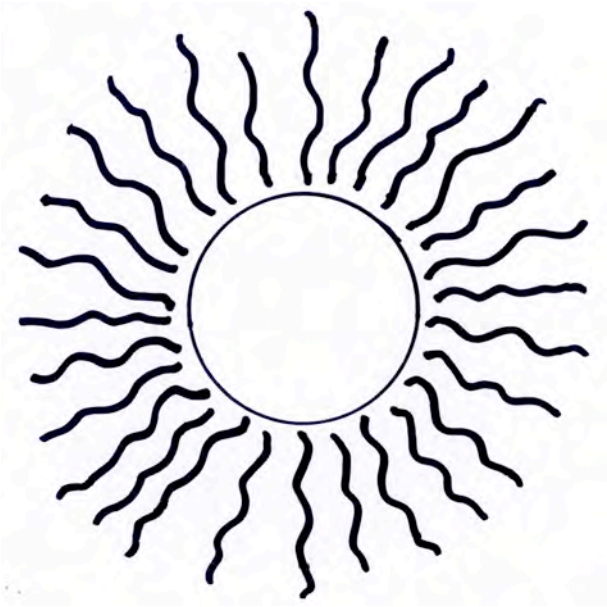
Pele’s sister Kapoulakinau danced this hula on the island of Ni‘ihau. It is considered one of the earliest of hula; a hula ki‘i. This oli was shared with the Windward Ahupua‘a Kūpuna by Anakala Kimo Awai of Hilo along with the Hilo district’s kūpuna. He also taught its motions.
It is both a chant of welcome to the morning Sun in the sky as well as a request for inspiration from ke akua, the creation, or our ancestors.

Kānehoalani

E Kānehoalani ē, Kānehoalani ē Aloha kāua! Kau ka hōkū ho‘okahi, hele i ke ala loa Aloha kama kūkū kapa a ka wahine, he wahine lohi‘au. Nānā i ka makani, he makani lohi‘au, hā‘upu mai o loko ē.	O Kānehoalani, Kānehoalani Greetings to both of us! The single star hangs suspended, moving on the long pathway Greetings to the kapa-beating descendants of the woman, a languid woman. Look to the wind, a slow-moving wind, that recalls that which is within.

The students of Kamakau Public Charter School chant this oli every morning to greet the Sun and establish a personal relationship to the natural world. The chant makes it clear that Hawaiians understood that the Sun is a star and that there is a regular pathway that the Sun appears to travel as our Earth makes it annual rotation around the Sun. The chant also refers to the legend of the god Māui who slowed the movement of the Sun in the sky so that his mother’s kapa would have more time to dry. The chant was passed on to Kamakau via a teacher who learned it from Pualani Kanahele.

Heating Up!
Student Reading 1



Energy from the Sun arrives on Earth in the form of shortwave solar radiation. The short wavelengths pass right through the atmosphere. Some of the energy is absorbed by the planet, warming us up. But there is something else that keeps us warm. There is a blanket of gases in our atmosphere, often referred to as "greenhouse gases." The Earth re-radiates energy back to space in the form of longer wavelengths (infrared radiation). These longer wavelengths can be absorbed by greenhouse gases, which then re-radiate some of the heat energy back to Earth.

What is a greenhouse gas?

Greenhouse gases are named for the effect that gases, such as carbon dioxide (CO_2) have on the atmosphere. If you have ever been in a greenhouse or in a car with closed windows, in the Sun, you know how much warmer it is inside the greenhouse or the car than it is outside. So-called greenhouse gases that build up in the Earth's atmosphere act like the roof of the greenhouse—they absorb and re-radiate heat and warm our planet.

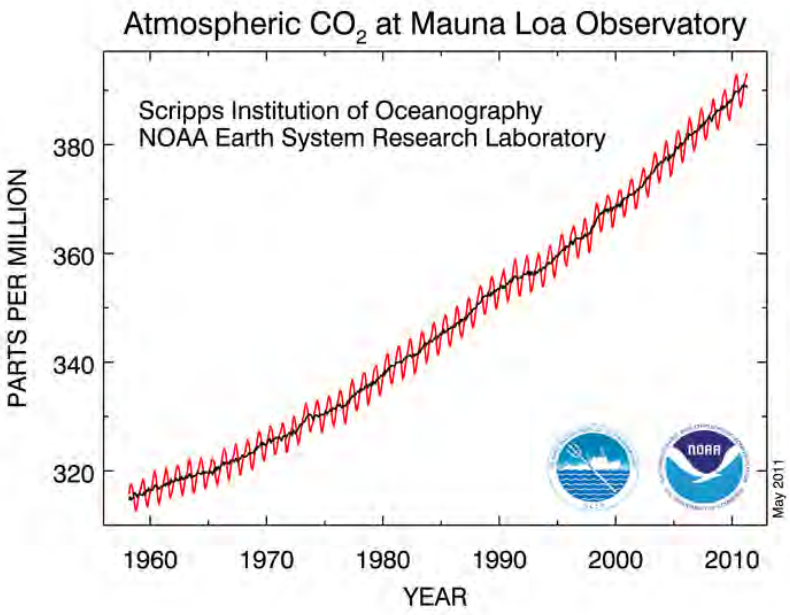
Scientists believe that CO_2 is the greenhouse gas that is contributing most to the recent period of global warming. This is partly because CO_2 is so long-lived in the atmosphere. Over half of the CO_2 produced by human activity since the beginning of the Industrial Revolution is still in the atmosphere (Flannery, 2005).

Lā - The Sun

In early Hawai'i, people had a deep respect or reverence for all of the natural world, including Lā (Sun). They chanted to Lā, welcoming it in the morning sky, and at the same time, requesting inspiration from ke akua, the creation, or Hawaiian ancestors. When we have reverence for the natural world, our actions reflect that respect and we live in a way that seeks balance with all forms of life. Today, there are many signs that natural systems on our planet are out of balance. The greenhouse gases in the atmosphere are building up. This increase has set in motion a series of changes on Earth, known as climate change. These changes are the focus of the investigations in this unit.

Measuring Carbon Dioxide

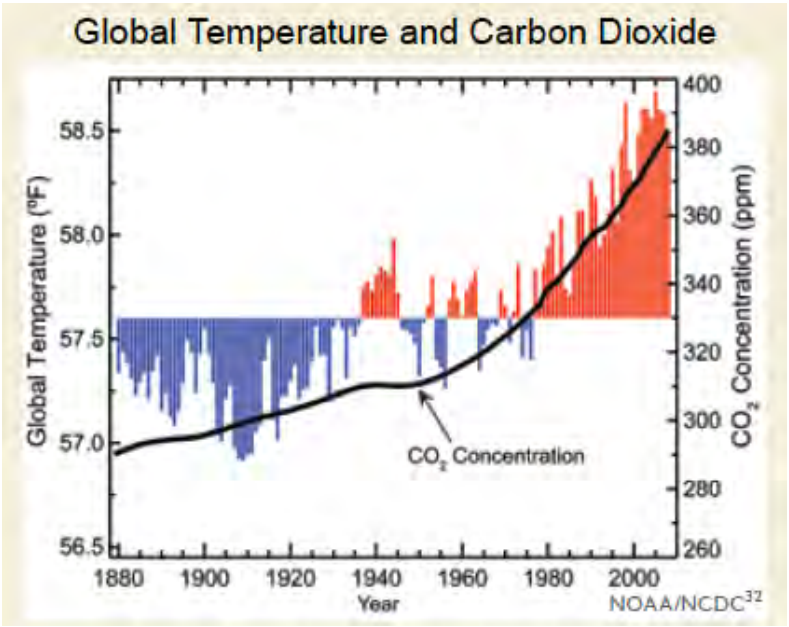
High atop Mauna Loa on Hawai'i Island, scientists have been recording carbon dioxide levels in the atmosphere since 1958. Look at the graph of their findings on the following page. What does it tell you is happening? Record your response on **Learning Log 1**.



The rise in CO_2 probably began many years before, as byproducts of the Industrial Revolution, a growing population, and the increased burning of fossil fuels. Scientists have drilled deep into ice sheets to learn about the Earth's climate changes. Data from ice cores spanning almost a million years demonstrates that during cold periods, CO_2 levels were around 160 ppm (parts per million).

Global Temperatures and Carbon Dioxide

The graph of global temperature and carbon dioxide changes shows the global annual average temperature (as measured over both land and sea). The blue bars show temperatures below average for the time period, and the red bars show temperatures above average. The year-to-year fluctuations are due to natural processes such as the effects of El Niños, La Niñas, or large volcanic eruptions.



By 2100, the global average temperature is projected to rise by 2° to 11.5° F (1.1° to 6.4° C). To keep the temperature increases in the lower end of this range, we need to reduce our carbon dioxide and other greenhouse gas emissions.

What can you conclude from this graph? Record your observations on **Learning Log 1**.

Graph courtesy of *Global Climate Change Impacts in the United States*. 2009

LEARNING LOG 1: GREENHOUSE EFFECT

NAME_____ **DATE**_____

After reading the information and studying the graphs in Student Reading 1, answer the questions below.

Interpreting Data...

1. What does the carbon dioxide (CO_2) data collected on top of Mauna Loa tells us?

2. What does the graph of global temperature and carbon dioxide change tells us?

3. What trends do you see in these graphs? When do these trends begin?

4. What human activities increase greenhouse gases in the atmosphere?

5. Complete the diagram below so that it shows how the greenhouse effect works. Write a caption to explain the diagram. Include an explanation of what happens when humans add more greenhouse gases to the atmosphere.

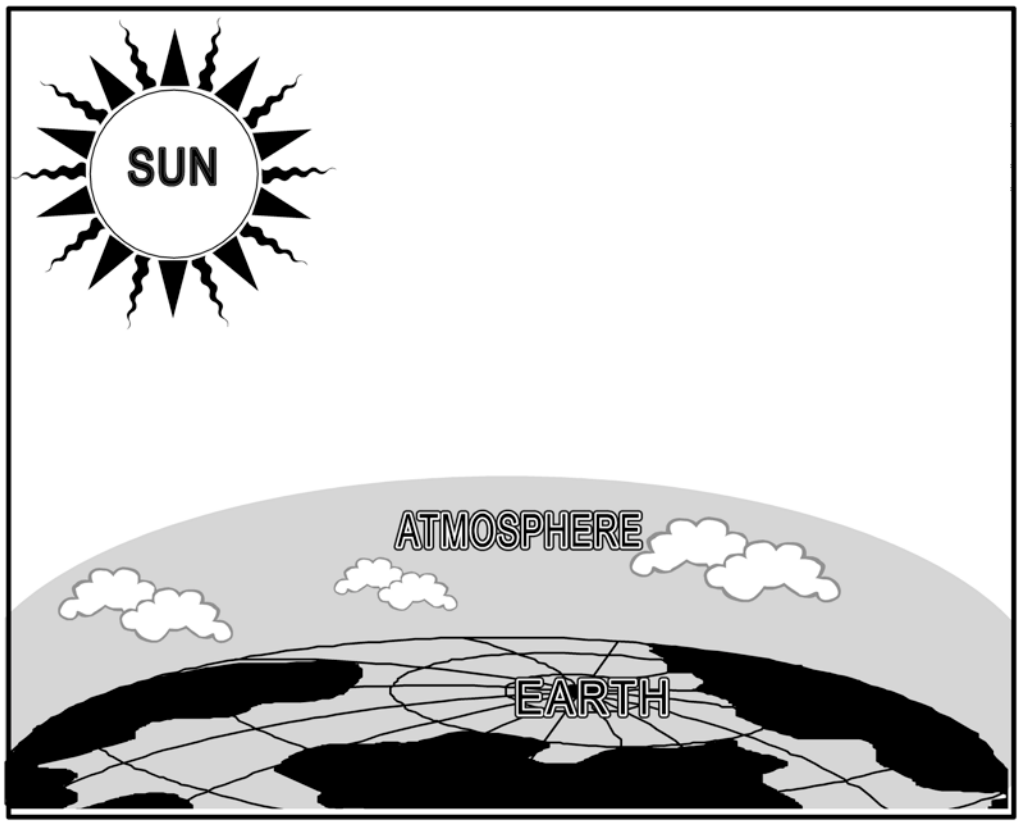


Diagram not to scale.

Write a caption:

6. Summarize how the needs of society and our modern technology have contributed to climate change.

LEARNING LOG 2: CARBON CYCLE

NAME_____ **DATE**_____

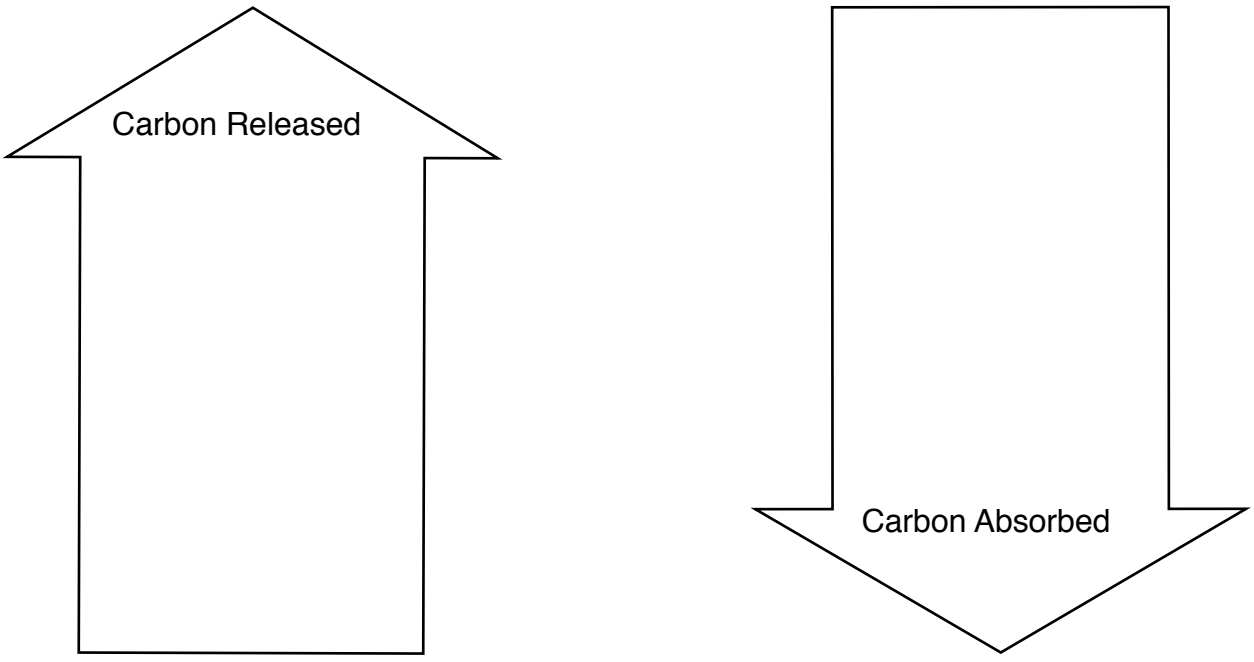
What is happening here? Taking notes...

Review the animation of the carbon cycle (either as a class, or on your own if computers are available). Go to the Environmental Protection Agency Kid's page: http://www.epa.gov/climatechange/kids/basics/today/carbon-dioxide.html.

1. What are the natural ways that carbon is absorbed? Are you a part of this cycle? Explain.

2. Use the words below to fill in the arrows showing the processes where carbon is released and processes where carbon is absorbed as carbon cycles between the land/ocean and atmosphere.

Write a caption for your arrow diagram that explains how carbon changes form in the carbon cycle. For example, from a gas to a solid.



ocean and land plants - photosynthesis
plants and animals die - decomposition
living things - respiration
volcanoes - eruptions
animals - feeding
fossil fuels - deposits

3. Draw your own arrows below to show how the carbon cycle is out of balance. Use the words from the labels above and add new terms below. Write a caption for your arrows.

forests - burning
fossil fuels - burning

4. Write a reflection about your personal connection to natural elements and how the needs of society today are impacting the planet.

VOCABULARY PRACTICE 1

NAME_____ **DATE**_____

Write a definition for each of the following terms:

Carbon

Carbon cycle

Carbon dioxide

Climate

Climate change

Fossil fuel

Greenhouse effect

Greenhouse gases

Mālama ʻāina

Radiation

Weather

STUDENT RESOURCES

WEBSITES

A Student's Guide to Global Climate Change
http://www.epa.gov/climatechange/kids/basics/today/greenhouse-gases.html Check this site to answer questions such as:

- What is the greenhouse effect?

- What else besides CO_2 is a greenhouse gas and where do these gases come from?

- Which greenhouse gases are produced in largest amounts?

Visit the following websites to continue your research into climate change:

- Check the animated graph for rising temperatures and CO_2 in atmosphere at: http://arcticclimatemodeling.org/Movies/data_analysis_dvd_sample.html

- Check climate change facts for students: http://arcticclimatemodeling.org/Movies/climate_change_dvd_sample.html

- Check out this site to get more of the basics on climate change: http://www.pewclimate.org/global-warming-basics/kidspage.cfm. See also: http://climatekids.nasa.gov/nasa-research/

BOOKS

Cherry, Lynne and Gary Braasch. *How We Know What We know About Our Changing Climate. Scientists and Kids Explore Global Warming*. Nevada City, CA: Dawn Publications. 2008.

David, Laurie and Cambria Gordon. *The Down-to-Earth Guide to Global Warming*. New York: Orchard Books, an Imprint of Scholastic, Inc. 2007.

Sussman, Art. *Dr. Art's Guide to Science. Connecting Atoms, Galaxies, and Everything in Between*. San Francisco, CA: Jossey-Bass in partnership with WestEd. 2006

Warming and Melting

How is climate change affecting the oceans?

Activity at a Glance

Students investigate how thermal expansion of the oceans and melting glaciers and ice sheets all contribute to global sea level rise. They develop hypotheses and work with models on a thermal expansion experiment. Students create a chain-of-events scenario depicting how melting of sea ice contributes to global warming.

Key Concepts

- The increase in global temperature due to the greenhouse effect is believed to be raising sea level due to:
  - expansion of the ocean caused by decreased water density due to warming, and
  - more fresh water from melting of glaciers and ice sheets.
- When reflective ice and snow melts, the Earth's albedo (reflectivity) decreases, which leads to increased warming.
- The oceans are a carbon "sink", which means that they absorb carbon dioxide from the atmosphere. As the oceans warm, their ability to absorb carbon dioxide decreases.

Skills

Activating prior knowledge, analyzing, inferring, collaborating, developing hypotheses, using scientific vocabulary, writing

Assessment

Students:

- Develop a testable hypothesis and complete an investigation to demonstrate how warming water expands, and infer how warming oceans could lead to sea level rise.
- Draw a chain-of-events diagram to explain how melting of sea ice decreases the Earth's albedo (reflectivity), accelerating global warming.
- Explain how the warming of the ocean affects its ability to absorb CO_2 from the atmosphere.

Hawai'i State Standard Benchmarks

Science 1: The Scientific Process - Scientific Inquiry

- **SC6.1.1** Formulate a testable hypothesis that can be answered through a controlled experiment.
- **SC.6.1.2** Use appropriate tools, equipment, and techniques safely to collect, display, and analyze data.

Science 6: Nature of Matter and Energy - Energy and its Transformation

- **SC.6.6.1** Compare how heat energy can be transferred through conduction, convection, and radiation.
- **SC.6.6.5** Explain how matter can change physical or chemical forms, but the total amount of matter remains constant.

Ocean Literary Principle 3

- The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water.

Nā Honua Mauli Ola

'Ike Na'auao - Intellectual Pathway

- **NHMO.6.14** Continue to develop personal communication, participation and collaboration skills.

Suggested Timeframe

Four 45-50-minute class periods

Day 1: Introduction, carbon cycle game, warm and cold soda demo

Day 2: Part 1 - Warming seas experiment

Day 3: Part 2 - Sea ice / land ice demo

Day 4: Summary and formative assessment - Learning Log 4

Materials

Provided

- Student Reading 2: Warming and Melting
- Learning Log 3: Warming
- Learning Log 4: Warming and Melting
- Vocabulary Practice 2

For You to Provide

- Two cans of soda; one warm, one cool
- Thermal expansion demonstration materials - For each team of 4 - 5 students: (Option: Conduct as a class demonstration using 150 watt lamp as heat source.)
  - 2 identical glass bottles
  - 2 rubber stoppers or use play-dough to make stoppers (See Resources at end of lesson.)
  - 2 thermometers
  - 2 clear glass straws
  - blue food coloring
  - ruler
- Small black garbage bags
- Small white garbage bags
- Masking tape or marking pen
- Two quart containers of ice
- 1 pitcher to hold melted quart of ice
- Clear cylinder or vase
- Computers for student research

Getting Ready

- ✓ Make a copy of Student Reading 2, Learning Logs 3 and 4, and Vocabulary Practice 2 for each student.
- ✓ Cool a can of soda and leave another can of soda at room temperature.
- ✓ Preview the following websites for pages with video, animations, photographs and information to enhance this lesson:
  - ✓ Conservation Council for Hawai‘i: http://www.conservehi.org/content/climate_change.htm
  - ✓ - Prepare to project video of the Jakobshaven Glacier in Greenland melting.
  - ✓ Windows to the Universe: www.windows2universe.org/earth/polar/polar_climate.html - Prepare to project the NASA satellite images showing ice cover in the Arctic in 1980 vs. 2003. Also prepare to project the carbon cycle game: http://www.windows2universe.org/earth/climate/carbon_cycle.html
  - ✓ NASA. Global Climate Change, Vital Signs of the Planet. Global Ice Viewer: http://climate.nasa.gov/interactives/global_ice_viewer/. Select a topic and view the images that show the changes in glaciers, sea ice, and continental ice sheets around the globe.
  - ✓ Geophysics Institute, University of Alaska Fairbanks: Multimedia presentations about climate change in Alaska: http://arcticclimatemodeling.org/multimedia.html
    - ✓ Under Multimedia Presentations, Unit 2, Earth’s Water, click on *Moving Molecules*, (image #5) (Note: other options are suggested for students to research on Learning Log 4.)

VOCABULARY

Albedo: a measure of the reflectivity of different surfaces on Earth

Conduction: the process of warming where a molecule is warmed and begins to move rapidly, passing heat to the next molecule

Convection: the movement of molecules because of differences in density, caused by heating

Glacier: slowly moving river or mass of ice that forms from compacted snow

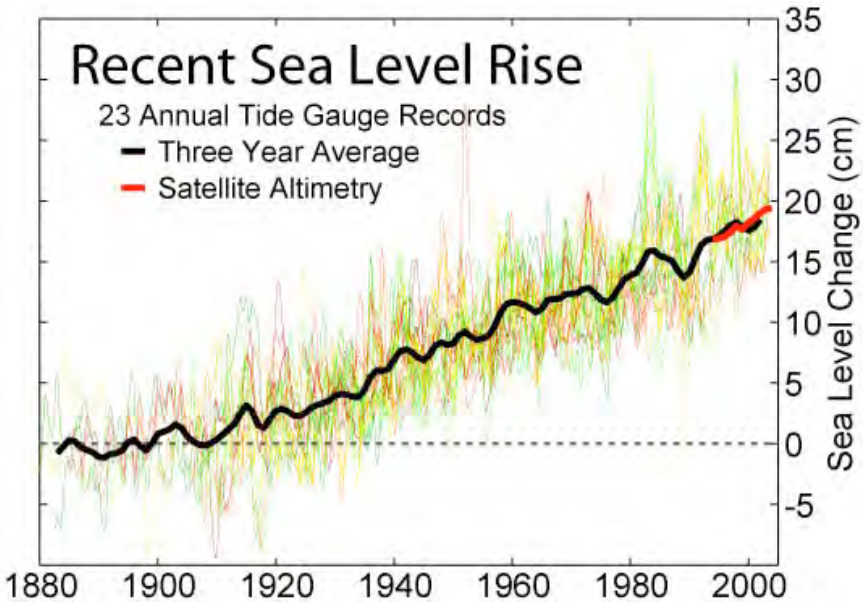
Ice sheets: the massive icy tops of Greenland and Antarctica; glaciers larger than 50,000 sq. km

Sea ice: ice that forms from seawater

Thermal expansion: in this context, the process of ocean water increasing in volume as the water temperature increases

TEACHER BACKGROUND INFORMATION

"Global warming and its consequences present new challenges to modern society. Among these is a degree of uncertainty among scientists about how to communicate the dramatic environmental changes that may be in store... Global SLR (sea level rise) has accelerated in response to warming of the atmosphere and the ocean, and melting of the cryosphere. Projections indicate that a 1 m rise by the end of this century is plausible." (Fletcher 2009)



Source: http://en.wikipedia.org/wiki/File:Recent_Sea_Level_Rise.png

Sea Level Rise

Using data from satellites carrying altimeters, scientists have calculated the rate of sea level rise. The global rate of sea level rise has accelerated since 1993. From 1993 to 2011, the global mean sea level has risen approximately 2 in (5 cm), which is a rate of about 3.3 mm/yr (Fletcher 2009). The rate of global sea level rise predicted for the end of this century is a mean for the planet. There is a lot of variability for different locations, with some areas actually experiencing lower sea levels. It is a complex process involving ocean currents, winds, and other factors. In Hawai‘i, sea level is predicted to be 3.3 ft (1 m) higher by the turn of the century (Fletcher 2009). More recent research takes into account the inundation of groundwater in low-lying areas of Honolulu as sea level rises. Since groundwater tables in low-lying areas are near the ground surface, the combined effect of flooding due to sea water inundation and flooding due to groundwater rising to the surface, doubles previous predictions of flooding (Rotzoll and Fletcher 2012).

Sea level at any one place can change for two principle reasons:

1) If more water enters the ocean through precipitation and run-off than leaves through evaporation and/or the water in the ocean expands through heating, then sea level will rise globally. This is known as a “eustatic” change in sea level.

2) The local area can sink tectonically for any of several reasons, such as withdrawal of ground water or additional weight added to the area through volcanism or deposition of sediment. If the ground sinks, then sea level will be seen to rise. But this is a “local” rise in sea level and only occurs in those areas that are sinking.

A good example of this is the difference in sea level rise measured in Honolulu and Hilo. According to the Hawaiian Volcanoes Observatory, sea level rose about 8 in (20.3 cm) in Hilo during the last half of the 20th century. During the same period, sea level rose only about 3.5 in (8.9 cm) in Honolulu. The difference is the 4.5 in (11.4 cm) that Hilo sank relative to Honolulu over that 50-year period. The reason for this difference lies in the great weight of the islands that slowly bends the underlying lithosphere. As the volcanoes grow, their weight is greater than the lithosphere can support. The result is that the lithosphere flexes downward under the increasing weight of the growing island. The downward flexing is a response to increases in the weight of the island, and is most rapid while the island is rapidly growing. The older Hawaiian Islands, such as O‘ahu and Kaua‘i, have already completed their periods of rapid growth and rapid subsidence. Their much slower subsidence rates result in much smaller changes in relative sea level, whereas Maui and Hawai‘i Island are still growing and sinking more rapidly, hence have more rapidly rising sea level.

The two main phenomena that contribute to global sea level rise due to climate change are the focus of this lesson: thermal expansion and melting ice.

Thermal Expansion

As water temperature increases, the density of water decreases, which causes the volume of ocean water to increase. Increased temperatures result in an increase in the average energy of motion of the water molecules, causing the water to expand when heated. Using modeling and observations of both deep and surface water, scientists calculate that thermal expansion of

seawater is estimated to have caused as much as 0.2 in (0.5 cm) of sea level rise per decade during the 20th century, and 0.7 in (1.7 cm) of sea level rise in the first decade of this century (Fletcher 2009).

Melting

Over the last 30 years, scientists have used satellites to record changes in ice cover on Earth. Their data show an 8% loss in Arctic sea ice over these three decades. This percentage is equivalent to approximately 390,000 sq mi (one million sq km) in area. In addition, sea ice in the Arctic is about 10 to 15% thinner than past measurements (ACMP 2009). National Aeronautics and Space Administration (NASA) scientists studying the Arctic sea ice conclude that natural variability and build up of greenhouse gases that have warmed the planet have probably combined to melt greater amounts of Arctic sea ice. Some of the scientists' models predict that by the end of the 21st century, there could be an ice-free Arctic for at least part of the year (NASA n.d.)

Source: NASA & Natural Resources Defense Council

Image provided courtesy of the Pew Center on Global Climate Change. www.pewclimate.org

According to NASA, more than two trillion tons of land ice in Greenland, Antarctica, and Alaska have melted since 2003 (Schweiger 2009). In 2007 nearly 19 billion more tons of ice melted than any year since 1979, when satellite measurements began (Schweiger 2009). The Greenland ice sheet holds roughly 8% of all of the fresh water on the planet. Over the last decade, the pace of melting ice in Greenland has accelerated 250% (Fletcher 2009). Mountain glaciers are also melting and retreating across the planet. The melt of ice sheets and glaciers combined is believed to contribute about 0.04 - 0.08 in/yr (1 - 2 mm/yr) to the global increase in sea level. While the

numbers may appear small, this is a cause of great concern for potential sea level rise over this century and disruptions in both ocean circulation and heat transfer in the atmosphere.

Albedo Effect

Albedo is a measure of the reflectivity of different surfaces on Earth. The light color of ice and snow reflects up to 90% of the Sun's energy back out to space. As the ice and snow melts, the Earth's albedo (reflectivity) decreases. When ice melts, less heat is reflected from the snow and ice and more heat is absorbed by the dark surface of the sea. The exposed ocean also allows more evaporation of moisture into the atmosphere, which increases precipitation. This positive feedback loop begins with warming, which causes melting of sea ice, which changes the albedo and increases energy absorption, which leads to more warming.

Impacts on the Ocean Circulation

Another impact from melting ice and snow is the potential disruption to the great ocean conveyer belt--the circulation of warm surface currents from the tropics to colder regions where cold water sinks and flows back to the tropics as a deep moving current. These massive convection currents are driven by differences in salinity and temperature. Colder, saltier water sinks; warmer, less salty water rises. With the increased melting of ice, more fresh water is being added to this system, lowering salinity and density. With the melting of glacial ice, the surface water in the colder regions of the planet becomes less dense. Since it's the cold, salty dense water sinking from the surface that helps to drive the ocean circulation, scientists are concerned that this increase in fresh water could interfere with the ocean conveyer belt currents (NASA 2011). It is a complex process and one that scientists continue to study as the potential for disruption to currents could affect not only ocean circulation, but weather patterns as well, including the potential for a major cooling effect on northern Europe (NASA 2011).

This pattern of ocean circulation also transports carbon around the world. CO_2 is taken up by the oceans in mostly temperate and sub-polar regions. And CO_2 is mostly released from the oceans in areas near the equator, especially in the Pacific Ocean (JCOFS 1990). Carbon is transferred from the surface of the ocean to deeper waters when marine plants and animals die and decompose and by the feeding of migratory zooplankton. This drawing down of CO_2 helps to remove some of the CO_2 building up in the atmosphere. However, as our oceans warm, the ability of the ocean to absorb CO_2 declines. The ability of seawater to dissolve gases (solubility) decreases with an increase in temperature, so warm water will simply hold less gas than cold water.

> "The world's oceans are the sleeping giant of carbon dioxide control. There is 20 times more carbon dissolved in seawater than occurs on land (in plants, animals and soil) and the release of just 2% of the carbon stored in the oceans would double the level of atmospheric CO_2. Furthermore, each year around 15 times more CO_2 is taken up and released by natural marine processes than the total produced by the burning of fossil fuel, deforestation and other human activities."
>
> --Joint Global Ocean Flux Study, Scientific Committee on Oceanic Research

TEACHING SUGGESTIONS

Introduction

1. **Introduce the focus question for this lesson.**

   Focus Question: *How is climate change affecting the oceans?*

   - Ask students to share their initial answers to this question.
   - Record what they know and what they wonder about in the K-W-L chart that was constructed in Lesson 1.

2. **Play the online carbon cycle game:** http://www.windows2universe.org/earth/climate/carbon_cycle.html**.**
   - Review what students learned about the carbon cycle in the previous lesson.
     - How does carbon move between the atmosphere and the ocean?
     - Project the online carbon cycle game and play it with students. Divide the class into teams and let teams take turns deciding which direction to move in the carbon cycle and have them take turns answering the quiz questions.
     - Discuss what they learned in the carbon cycle game and introduce questions to think about:
       - How does carbon change forms as it moves through the cycle?
       - If we increase CO_2 in the atmosphere by burning fossil fuels, won't the ocean just absorb it?
       - With increased greenhouse gases, the ocean is warming. How will this warming affect the carbon cycle?

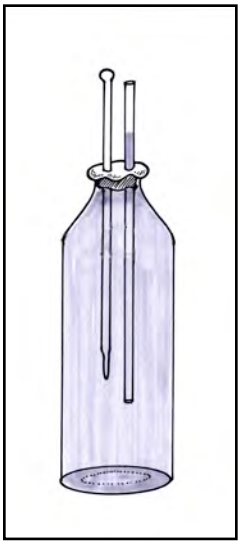
3. **Conduct a demonstration to compare the ability of warm vs. cold liquid to absorb carbon dioxide.**
   - Show students a warm can and a cold can of soda and ask them what makes the "fizz" or bubbles in soda. (Bubbles are carbon dioxide gas trapped in the liquid soda.)
   - Ask students to predict which soda will hold onto carbon dioxide longer--the cold or warm soda? Why?
   - Use an ELMO or overhead projector and pour the sodas into two clear glasses and observe what happens. (CO_2 bubbles will escape more quickly from the warmer soda.)
   - Discuss the demonstration.
     - If warm liquids hold less CO_2 than cool liquids, what might we infer is happening in the warming oceans?
     - How will this affect the balance of the carbon cycle?
     - Could the warming of the oceans affect sea level? How?

Part 1: Warming "Seas" Experiment

4. Challenge students to conduct an investigation to find out if heating water will cause it to expand in volume.

- Ask students if they think the volume of water will increase when it is heated. Discuss their ideas.
- Show students the animation of water molecules on the University of Alaska Geophysics Institute's webpage: http://arcticclimatemodeling.org/multimedia.html Under Multimedia Presentations, Unit 2 Earth's Water, click on *Moving Molecules* (#5).
- Discuss how the increase in temperature increases the movement of the water molecules, and due to this motion, most substances expand when heated.

5. Show students the materials for them to investigate thermal expansion of water.*



- Divide the class into teams of four to five students.
- Hand out **Learning Log 3** and review it with students.
- Ask student groups to work together to write a testable hypothesis using the materials available to investigate if the volume of water will expand when heated.
- Hand out the materials for the models.
- Explain that the method of heating the water in the bottles is up to students to figure out. Show them the possible materials for heating their water in the Sun (or use 150 watt lamps) including black or white bags. Students can opt to use any combination of these materials.
- (They will discover that the best means of heating the water in the bottle with the materials provided is to place the bottle on a black bag in the Sun or under a lamp. It should take approximately 10 minutes for the water to rise in the warming bottles.)

Remind students to be careful with glass containers that they are warming in this experiment.

✶ This investigation was adapted from Centers for Ocean Sciences Education Excellence and National Earth Science Teachers Association, Windows to the Universe.

6. Discuss students' hypotheses and the need to set up a control.

- Discuss the variable that students are testing (heat) and the need to set up a control (no heat), but all other conditions being the same.

- Note if some students choose to try heating the water in bottles on white instead of black bags in the Sun, let them proceed so they can see difference. (The albedo affect will be discussed when students debrief.)
- Circulate and check on students' hypotheses, monitor their experiment set-ups, and remind them to:
  - Start with cool water filled to the top of the bottle.
  - Make a tight seal with the rubber stopper or playdough.
  - Mark the level of the water in the clear straw with tape or a marking pen at the start.
  - After inserting the clear straw into the stopper, pull the straw out, remove any playdough or material in the bottom, and reinsert it into the bottle.
- Emphasize **safe handling** of the glass bottles and thermometers!
- If none of the groups has chosen the light-colored materials for their experiment, set up a demonstration using a bottle on a white plastic bag in the Sun. This can be used later to discuss the albedo (reflectivity) effect of ice and snow.

NGSS:

Have students draw a diagram to demonstrate how adding heat to water causes the water particles to move faster and the water to expand. Infer how this relates to global sea level rise.

7. Bring groups together and discuss their findings.

Discussion Questions

- Did the water level go up in the straw? How much did it rise?
- Which processes of heat transfer are evident in this experiment? (convection - as the water molecules are heated, there is a decrease in water density, causing the water to rise)
- What can we infer from this experiment about sea level rise? Explain your thinking.
- Were there any experiments where the water did not rise? Why might there have been different results? (Use the light-colored experiment set-up here, if needed.)
- How do you think the light-color of the snow and ice in polar regions impacts the absorption of heat?
- How might the melt of more glaciers and ice sheets affect sea level?

- Ask students to complete **Learning Log 3** with their conclusions.

Part 2: Melting and Sea Level

8. Use Google Earth and explore satellite images of polar regions with the class.

- Have students locate Greenland on Google Earth and note the white ice sheet that covers approximately 80% of its surface.

- Ask students how the greenhouse effect and warming trend they learned about in the previous lesson may be affecting this ice sheet.
- Show students the video of the melting of Jakobshaven Glacier in Greenland at the CCH Website: http://www.conservehi.org/content/climate_change.htm and click on video.

9. Hand out Student Reading 2 and Vocabulary Practice 2.

- Conduct a jigsaw activity to help the students understand the reading. Divide the class into the following four groups and assign each group to closely read their section of the Student Reading:
  1) Global Warming
  2) Oceans and CO_2
  3) Melting Ice and Sea Level
  4) Albedo Effect

NGSS:

Have students write questions to clarify evidence about the rise in global temperatures and sea level rise due to melting. Ask them to share their questions and conduct research to seek answers. See resources listed at the end of the Student Reading.

- Circulate and assist students. Ask them to underline or highlight the key points in their sections of the reading. Have them add questions in the margins.
- Have students from the different groups gather in groups of four with an "expert" from each of the content areas. Ask each "expert" to share what was read with the other students.
- Ask student groups to complete the following tasks:
  - Explain how the albedo effect could increase global warming.
  - Describe the different kinds of ice: glaciers, sea ice, and ice sheets.
  - Write definitions for the vocabulary terms on the **Vocabulary Practice 2** page.
- Ask students if they think that the melt of sea ice, ice sheets and glaciers would have the same effect on sea level.
- Discuss their ideas and then conduct a demonstration to find out.

Group students with different abilities together to help ensure understanding of concepts.

10. Conduct a sea ice versus land ice demonstration.

- Place a large clear vase under a lamp with a 150 watt bulb. Fill about one-third of the vase with water and add blue food coloring.
- Add a quart-size block of "sea" ice and mark the level of the water in the vase as "sea level." Have a "glacier" block of ice melting on land (in a pitcher) nearby.
- Ask students to predict what will happen to the water level in the vase when the "sea" ice melts.
- When the "sea" ice melts, have students check the water level in the vase. Ask them why it did not rise. (Floating ice displaces its own

volume so when large quantities of sea ice melts, it should not cause sea level to rise.)

- Pour the "glacier" melt into the vase. Measure how much the water level changed. Ask students to compare and explain. (When sheet ice or glaciers from land melt, they add water to the oceans, causing sea level to rise.)

Part 3: Summarizing

11. Conduct a Think-Pair-Share with the following challenge: ***Draw a diagram to show how the melting of sea ice contributes to global warming.***

- Have pairs of students work together on the diagram for a few minutes. Remind them to think about the differences between sea ice, ice sheets, and glaciers.
- Call time and ask for volunteers to share their diagrams.

12. Distribute Learning Log 4 and ask students to complete it.

- Review students' Learning Log responses as a formative assessment.
- Revisit the K-W-L chart**.**
- Ask students to summarize what they have learned and list these summaries under the L on the chart.
- Have all questions listed under the W been answered? Have new questions been generated? Ask students to work individually or in teams to conduct some online research to answer questions.
- Review students' **Vocabulary Practice 2** pages. Have students add words and definitions to the **Word Wall** begun in Lesson 1.

EXTENDING THE LEARNING

- Have students conduct an experiment with convection currents to investigate the great ocean conveyer belt currents. See Extended Activity at the end of this lesson.

- Have students go online to the following NOAA website to research sea surface temperature changes: http://csc.noaa.gov/psc/dataviewer/. Click on the Oceans tab for information on changes to sea surface temperatures around the globe and pause the animation to see changes around the Hawaiian Islands.

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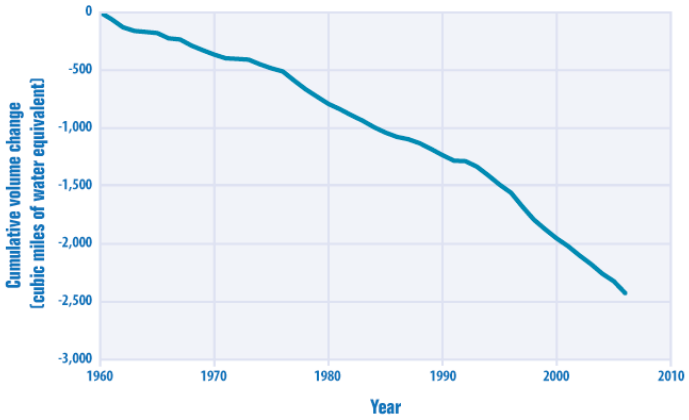
Resources

If you do not have rubber stoppers for the bottles used in this experiment, make playdough, which is pliable and can be used to prevent leaks. To make playdough, combine 1/2 cup salt and 1/2 cup water with 1 cup of flour and mix well.



Change in Volume of Glaciers, Worldwide, 1960 - 2006

Graph courtesy of EPA 2010

To view current graphs of recent changes in sea ice and land ice, see the NASA, Global Climate Change, Vital Signs of the Planet website: http://climate.nasa.gov/key_indicators/

VOCABULARY PRACTICE 2

NAME_____ **DATE**_____

1. Write a definition for each of the following terms:

Albedo

Conduction

Convection

Glacier

Ice sheets

Sea ice

Thermal expansion

2. **Choose one of the vocabulary terms and draw a diagram that helps to define it.**

LEARNING LOG 3: WARMING

NAME_____ **DATE**_____

Work with your team to find out if heating water will cause it to increase in volume.

Hypothesize...

1. Develop a testable hypothesis.

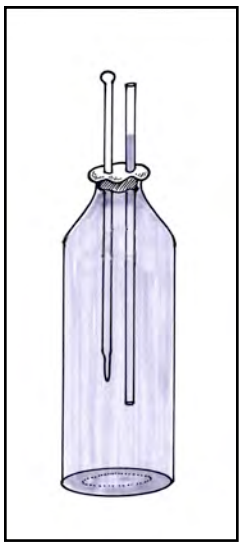
If_____

Then_____

Because_____

_____

2. Set up your experiment using 2 bottles filled to the brim with cool water, a stopper, blue food coloring, a thermometer, and a clear straw. Use tape to mark the level of the water in the straws. Use a ruler to measure changes in water level.



3. Decide how you will warm the water in the bottle using the materials your teacher provides.
4. Decide on the control you will set up for this experiment.

Materials

5. List the materials you will use in your experiment.

Procedure

6. Record your experimental design in the space below.

This investigation was adapted from Centers for Ocean Sciences Education Excellence and National Earth Science Teachers Association, Windows to the Universe.

Observe...

7. Record the temperature of the water in both bottles and the time when you begin.
   - Once the temperature starts to rise, record the temperature and the water level.
   - Continue recording the temperature every two minutes until the temperature stops rising.

Time (min)	0	2	4	6	8	10	12	14	16	18
Temp (°F or °C) - Bottle 1										
- Bottle 2										
Water Level (mm) - Bottle 1										
- Bottle 2										

Data Analysis

8. Use your data table to create a graph of temperature and water rise over time. Be sure to label the X and Y axes. Note: you will have two Y axes; one for temperature and one for water level.

Conclude... .

9. Was your hypothesis validated? Explain your findings and conclusion on a separate page.

Student Reading 2
Warming and Melting

Global Warming

Did you know that some parts of planet Earth are warming faster than other areas? The average temperature on Earth increased 1° F (0.5° C) during the 20th century. In the Arctic, the average temperature has increased 5.4° F (3° C) in the 30 years between 1970 and 2000.

Scientists believe that CO_2 (carbon dioxide) is the greenhouse gas that is contributing most to the recent period of global warming. This is partly because CO_2 stays so long in the atmosphere. More than half of the CO_2 produced by human activity since the beginning of the Industrial Revolution is still in the atmosphere (Flannery, 2005).

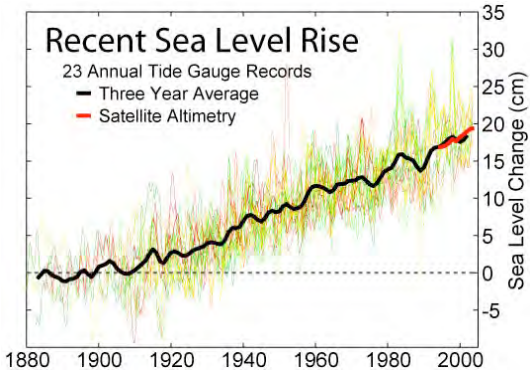
Oceans and CO_2

The ocean absorbs lots of carbon dioxide. Some scientists refer to the world's oceans as "the sleeping giant of carbon dioxide control" (JGOFS 1990). We know that carbon moves through the carbon cycle between land, atmosphere and oceans. But the oceans hold 20 times more carbon than there is in the plants and animals and soil on land. As our oceans become warmer, they are less able to absorb the excess CO_2 from our human activities.

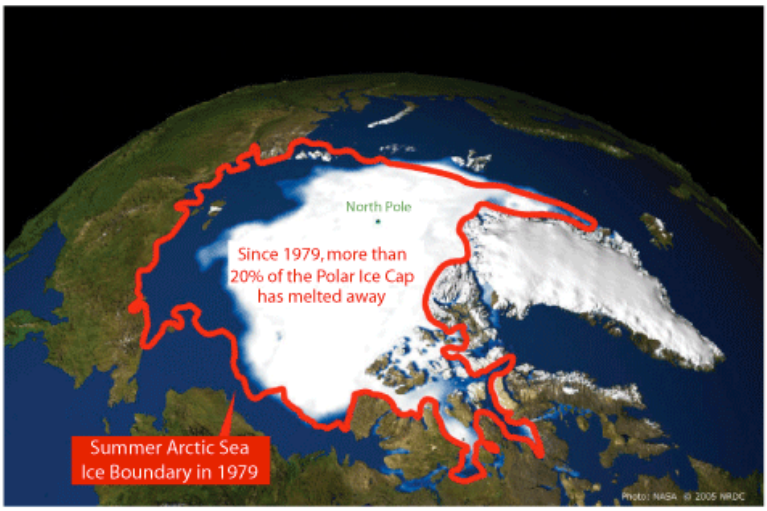
Melting Ice and Sea Level

The climate of the Earth has changed many times. Looking back, we know that 20,000 years ago, at the peak of the last ice age, sea level was 300 feet lower and about 30% of the Earth was covered in ice. As temperatures warmed, glaciers and ice sheets melted and sea level rose. In fact, geological clues on islands around the Pacific indicate that 5,000 years ago, sea level was a few feet higher than it is today. Then between 2,000 to 500 years ago, the climate cooled and sea level fell again on Pacific islands, and stopped falling a few hundred years ago (Fletcher 2009).

Now the glaciers and ice sheets are melting faster than scientists predicted they would and sea level has been gradually rising around the world. Since the climate has changed over time, why should we be concerned about the warming temperatures and ice melting today? The problem is that the *rate* of warming has never been so rapid. In the past, the warming periods of Earth's climate averaged 1 degree C every thousand years. Today human activities are warming the planet at a rate at least 10 times, and perhaps 40 times faster (Sussman 2006).



- There has been a tripling in the amount of ice melted in Greenland between 1996 and 2007 (NASA 2010).
- Since 1960, glaciers around the world have been melting and retreating. In the last decade, the pace of melting has risen. Where does the melting ice end up?



Source: NASA & Natural Resources Defense Council

Image provided courtesy of the Pew Center on Global Climate Change. www.pewclimate.org

Albedo Effect

Albedo is a measure of the reflectivity of different surfaces on Earth. The light color of ice and snow reflects some of the Sun's energy back out to space. But what happens when sea ice melts? Notice the dark color of the melted region in the Arctic. More energy is absorbed by the exposed dark surface of the sea. This leads to heating of the Arctic and Antarctic and more melting. Sea ice melt does not have a direct impact on sea level rise, but it does have an indirect influence. This is due to the increased warming that occurs from the newly exposed dark areas of the sea.

Explore:

How much is sea level rising? Look at the graph of data from tide gauge records around the world. What does this graph tell you? Record your answer on **Learning Log 4**.

Conduct some research to answer the questions and complete the diagram on Learning Log 4. To learn more about polar melting, visit these websites:

NASA. Global Climate Change, Vital Signs of the Planet. Global Ice Viewer: http://climate.nasa.gov/interactives/global_ice_viewer/. Select a topic and view the images that show the changes in glaciers, sea ice, and continental ice sheets around the globe.

Geophysics Institute, University of Alaska Fairbanks: Multimedia presentations about climate change in Alaska: http://arcticclimatemodeling.org/multimedia.html

- ✓ Under Interactive Multimedia, Unit 8 Climate Change Impacts, click on different images to learn more.

Windows to the Universe: http://www.windows2universe.org/earth/polar/icemelt_oceancirc.html

LEARNING LOG 4: WARMING AND MELTING

NAME_____ **DATE**_____

Draw a diagram and answer the questions below.

1. Describe each of the following and how they are different: sea ice, ice sheets, and glaciers.

2. Draw a chain-of-events diagram to show how the melting of sea ice contributes to global warming.

3. What trend is revealed by the graph of sea level change? How much has global sea level risen over the last century?

4. On the back of this page, write a paragraph to explain how climate change is affecting the oceans.

EXTENDED ACTIVITY

Ocean Currents

The Sun's energy drives the movement of winds in the Earth's atmosphere and currents in its oceans. As the Sun heats the Earth's surface, that heat is transferred to the Earth's atmosphere and in the oceans in a process called convection. These currents have strong influence on climates around the world.

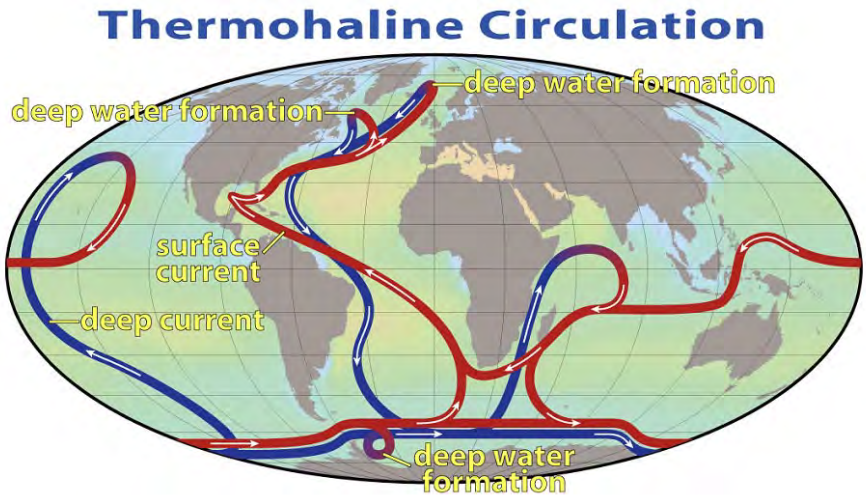


Image source: http://en.wikipedia.org/wiki/Thermohaline_circulation

The Sun heats the surface of the water in the tropics. Warm water is less dense than cold water, so it floats on top of dense, colder water beneath it. Think of diving into the ocean and feeling the temperature change on your body as you swim to lower depths. The warm surface water that heats up near the Equator moves north where it cools. Colder water is more dense (and saltier), so this cold, salty water sinks. The water is saltier because as sea ice forms above it, the salts are expelled into the water below making it saltier. The cold, dense water flows beneath the warmer surface water and makes its way back toward the equator along the bottom. This movement of water is referred to as the Great Ocean Conveyer Belt.

What do you think could happen to the circulation in the oceans of our planet when temperatures increase and more ice melts? Let's conduct a demonstration to find out more about ocean circulation. When you complete your investigation, find out how climate change may affect these major ocean currents and how it may actually cause cooling in some areas such as northern Europe. Go to Windows to the Universe webpage: http://www.windows2universe.org/earth/Water/circulation1.html

How could global warming cause cooling of Europe?

In the North Atlantic Ocean, surface water is drawn north to replenish the cold, salty water that sinks southeast of Greenland. With global warming, the ice sheet on Greenland is rapidly melting. When the fresh water from melting glacial ice flows out into the area where sea water normally sinks, it lowers the salinity of the ocean water. When the salinity is lower, the water is less dense. This will cause the sinking to slow down or even stop.

What will be the impact of this?

Northern Europe has a much warmer climate than similar latitudes in North America. For example, cold, windy New York City lies at nearly the same latitude as much warmer Rome, Italy, and sunny Madrid, Spain. Paris, France lies at the same latitude as the frigid U.S.-Canadian border between British Columbia and Washington state.

How can we explain this difference?

The Gulf Stream system of ocean surface currents brings warm water from the equatorial and tropical Atlantic to the North Atlantic Ocean. The part of the current system that delivers the warm water to Europe is called the North Atlantic Drift current. The current is pulled north by the cold water sinking southeast of Greenland. If the water stops sinking in the North Atlantic, then the current will not be drawn north and will flow much farther south toward Africa, depriving Europe of the warm water and its temperate climate.

Could this really happen?

Because we can't see into the future, the best way to answer this question is to see if we can find evidence of a similar situation having occurred in the past and examine what happened then.

Younger Dryas

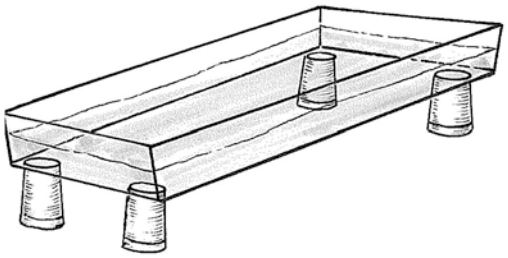
Between about 12,800 and 11,500 years ago, a cold period known as the Younger Dryas occurred. Also called the Big Freeze, this period saw a return to glacial conditions for Europe, interrupting the warming that had been occurring since the end of the last ice age. Data indicates that the cooling occurred as a result of the collapse of part of the North American ice sheet releasing melt water into the North Atlantic. This enormous quantity of fresh water reduced the density of the normally cold, salty surface water southeast of Greenland. This interrupted the sinking of this water and allowed the North Atlantic drift to head farther south, thus plunging Europe into a 1,300-year cold period.

So, one of the rather unexpected outcomes of global warming may be cooling of northern Europe.

Model of Ocean Circulation

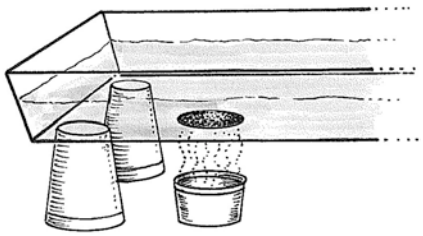
Instructions: Work together as a group to demonstrate how ocean currents are created. Record your observations in your **Learning Log**.

1. Collect all the materials you will need for this experiment.
2. Double up the Styrofoam cups. (You should have 2 cups doubled up to place under each corner of the pan, and 1 extra cup.)
3. Set up the pan as shown in the diagram below. Fill one-third of the pan with room temperature water.

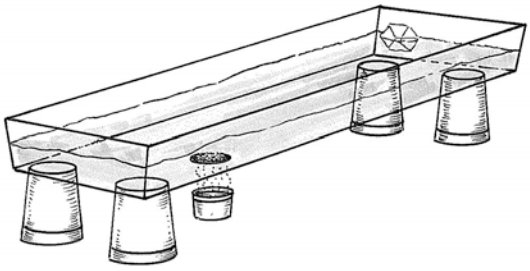


4. Make sure the water settles.
5. Carefully fill the extra Styrofoam cup with hot water. (The cup of water should be VERY hot or the experiment will not work.)Without disturbing the water, use the eyedropper to gently release a dot (the size of a quarter) of red food coloring into the bottom of the water at one end of the pan.

6. Part 1: Immediately position the hot cup of water under the dye. What happens? Record your observations in your Learning Log.



7. Part 2: Without disturbing the water, gently place the blue ice cube at the opposite end of the pan. What happens? Record your observations in Learning Log.



Part 3: Gently place a floating object on the side of the pan where the hot water cup has been positioned. What happens to your float? Record your observations in your Learning Log.

Carbon Consequences

How is climate change projected to affect shoreline communities in Hawai'i?

Activity at a Glance

Students view animated flyovers of "blue line" maps showing projected sea level rise in Hawai'i by the end of the century. Using the ratio of water depth to distance offshore where waves first affect the bottom, students predict how projected sea level rise will affect their beach profile. They work in teams to collect baseline data to share with their community.

Key Concepts

- A beach profile includes the distance (L) offshore where approaching waves first affect the bottom, and the depth at that place (D). Typically the ratio L/D is about 100.
- If the rate of carbon emissions continues at the present level, researchers project a rise of approximately 1 m (~3.3 ft) in sea level for Hawai'i by the end of the century.
- The consequences of climate change projected to affect shoreline communities in Hawai'i include sea level rise, erosion of beaches, increased threat from tsunamis and storms, and changes in water temperature and pH.

Skills

Activating prior knowledge, analyzing, inferring, collaborating, using scientific vocabulary, creating diagrams and maps, writing and communicating orally

Assessment

Students:

- Describe the ratio relationship they used to calculate a new beach profile based on projected rise in sea level.
- Collect and summarize data of ocean conditions.
- Write a reflection about the local consequences of global carbon emissions, including sea level rise, erosion of beaches, increased threat from tsunamis and storms, and changing pH and water temperatures.

Hawai'i State Standard Benchmarks

Science 1: The Scientific Process - Scientific Inquiry

- **SC.6.1.2** Use appropriate tools, equipment, and techniques safely to collect, display, and analyze data.

Science 2: Nature of Science - Science, Technology and Society

- **SC6.2.1** Explain how technology has an impact on society and science.

Common Core Standards

Math: Ratio and Proportional Relationships - Ratio Reasoning (RP)

- **RP.6.1** Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.
- **RP.6.3** Use ratio and rate reasoning to solve real-world and mathematical problems.

Language Arts: Speaking and Listening - Comprehension and Collaboration

- **SL.6.1** Engage effectively in a range of collaborative discussions with diverse partners on *grade 6 topics, texts, and issues*, building on others' ideas and expressing their own clearly.

Nā Honua Mauli Ola

'Ike Honua - Sense of Place Pathway

- **NHMO.8.5** Recognize and respond to the people, places, and natural elements in their community.

Suggested Timeframe

Four 45-50 class periods, plus half-day field study

Day 1: Introduction and Part 1 - The Blue Line

Day 2: Part 2 - Student Readings 3 and 4 and demo of shoreline retreat

Day 3: Collecting data - preparing for field study

Day 4: Field study

Day 5: Summarizing findings

Materials

Provided

- Student Reading 3: Changing Beaches
- Student Reading 4: Changing Oceans
- Student Data Sheets 1 - 3
- Vocabulary Practice 3

For You to Provide

- Meter stick
- Blue yarn
- Roll of butcher paper
- Chalk
- 10 Clipboards (2 for each team)
- 4 meter tapes (for field measurements)
- GPS receiver (if available)
- 1 pH test kit
- 2 thermometers
- 2 hydrometers
- Paper and markers (to make signs for 10-year, 50-year, and 90-year shoreline markers)
- Paper and pencils (to make maps)
- Digital camera
- Video camera (optional)

Getting Ready

For Classroom:

✓ Make a copy of the Student Readings and Vocabulary Practice 3 for each student.

✓ Create a large diagram of the shoreline profile provided in the Teacher Background section. Sketch the profile on butcher paper or use chalk on a large section of floor. Draw the profile to scale so that students can work with a large scaled drawing before going into the field. Suggested scale D = 5 cm; L = 500 cm (5 m). Allow room on the diagram for L to become 100 cm longer during the demonstration.

✓ Preview the following websites and prepare to project the blue line movies and other relevant pages in class:

- ✓ University of Hawai‘i, School of Ocean and Earth Science and Technology (SOEST), Sea Level Rise Website. Scroll down to bottom of home page to see Blue Line movies for O‘ahu, Kaua‘i, and Maui: http://www.soest.hawaii.edu/coasts/sealevel/
- ✓ SOEST Coastal Geology Group. Data Resources. Shoreline Imagery for the Hawaiian Islands. http://www.soest.hawaii.edu/coasts/data/
- ✓ Internet4Classrooms. 6th Grade Interactive Math Skill Builders: http://www.internet4classrooms.com/skill_builders/ratio_proportion_math_sixth_6th_grade.htm

For Field Study:

✓ Check the tide calendar to select a day for taking students in the field when it will be low tide. Make arrangements for field study, including asking parents or others in the community to help.

✓ Review the Student Data Sheets and copy sets of the data sheets so that each team has one data sheet or one data sheet per person. (See Teaching Suggestion 5.)

Vocabulary

Ocean acidification: the process where seawater becomes more acidic due to increased CO_2 dissolved in the water

pH: a measure of how acidic or alkaline a solution is, measured on a logarithmic scale of 1 – 14, where 7 is neutral, numbers below 7 are acidic and above 7 are alkaline

Ratio: a comparison of two quantities

Salinity: the total amount of dissolved material (salts) in seawater; denoted as ppt (parts per thousand)

Tsunami: a series of waves produced by earthquakes, volcanoes, or landslides

Teacher Background Information

University of Hawai'i researcher, Charles Fletcher, predicts a 3.3 ft (1 m) rise in sea level for the Hawaiian Islands by the end of this century. With this higher sea level, shoreline communities will undoubtedly experience:

- seawater inundation of low-lying coastal areas
- erosion of beaches
- salt water intrusion into groundwater and ecosystems
- higher water tables
- increased flooding and damage from heavy rainfall and storms

(Fletcher 2008.)

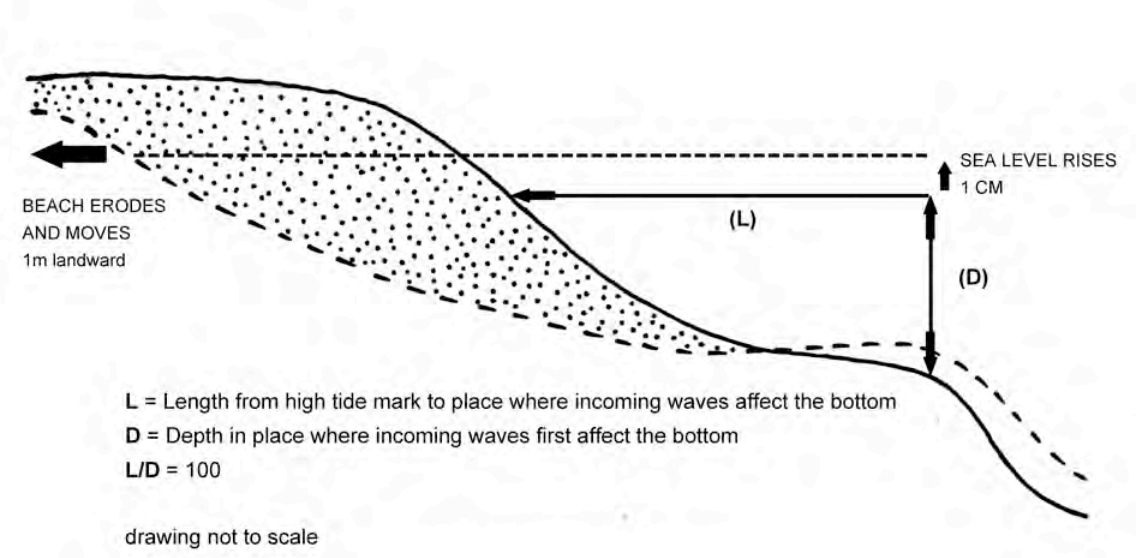
Ocean flooding and erosion of beaches and bluffs have already had dramatic impacts in coastal communities around the globe. For island communities, especially low-lying atolls, these impacts are a cause of great concern. In preparation for increasing sea levels, at least one low-lying Pacific Island nation, Tuvalu, has already negotiated a nation-wide immigration of its citizenry to New Zealand (Flannery, 2005), and some of its citizens have immigrated to Australia due to sea level rise impacts. Over the last decade, the sea level in Tonga appears to have risen by about 4 in (10.2 cm). Twelve other Pacific monitoring stations also show a steady rise, but not as much as in Tonga (Dorney, 2006).

Beach Erosion

Following is an excerpt from Fletcher et al 2010: *Living on the Shores of Hawai'i: Natural Hazards, the Environment, and Our Communities*. Chapter 9.

"The exact relationship between an increment of sea-level rise and an increment of shoreline retreat is not well understood. Hence, it is difficult to predict how much erosion will be caused by sea-level rise. But it is possible to make an estimate. The width, steepness, and geometry of a beach have a characteristic form that depends on the size of sand grains and the energy of waves. Coarse sand grains tend to build steep beaches, and fine sand grains tend to build beaches with gentle slopes. High waves will move these grains offshore and lower the slope, promoting gently dipping beaches that can dissipate the wave energy further offshore. These are referred to as *dissipative beaches*. Beaches that are steep and tend to reflect wave energy back toward the ocean are called *reflective beaches*. Most beaches exist in a state of dynamic equilibrium among these factors, constantly shifting from reflective to dissipative and accumulating a range of sand grains, as the tides, winds, and waves vary throughout the year.

"Scientists use a beach profile, a topographic cross-section of a beach, to describe these shifts in geometry. A beach profile is measured perpendicular to the shoreline and runs from the land to the sea. It includes the dune, the dry sand beach, the foreshore, and the offshore portion of a beach in the surf zone. The profile can be described by the distance (L) offshore where approaching waves first affect the bottom and the depth at that place (D). Typically the ratio L/D is about 100, though it can vary between fifty and two hundred depending if the beach is reflective (closer to fifty) or dissipative (closer to two hundred).



Retreat of Shoreline with Sea Level Rise

"As sea level rises, the profile shifts landward and upward to regain its equilibrium profile; the L/D ratio of ~100. It achieves this by eroding the shoreline, which on a natural beach should consist of a sand-rich dune. If however, the shoreline consists of a lava outcrop, a clay bank, a seawall, or some other non-sandy barrier, the beach will experience a sand deficiency and will eventually disappear. Since L/D is approximately 100, the change in D due to sea-level rise can translate into horizontal beach erosion two orders of magnitude greater than D. Hence, with global sea-level rise currently at approximately 0.12 in/yr, this translates to one foot per year erosion. Notably, this is about the average rate of coastal erosion that has been measured on the islands of Kauai, Maui, and O'ahu. However, the tide gauges among these islands do not record rates of rise equivalent to 0.12 in/yr. They record lower rates of sea-level rise, closer to 0.06 to 0.1 in/yr. Hence, if beach erosion were responding only to sea-level rise the average rate would be less than we measure. Either our estimate of L/D is incorrect and should be closer to 200, or beaches are affected by more factors than just sea-level rise (for instance they can be affected by human impacts to sand availability) or some combination of these.

"If we stick with L/D ~ 100 as a best-case scenario, the amount of shoreline retreat accompanying a 1 m (40 in) rise in sea level by the end of the century will be approximately 100 m or 330 feet. This amount should serve as a guideline for developing tools to manage beach conservation and coastal hazard mitigation under our warming climate."

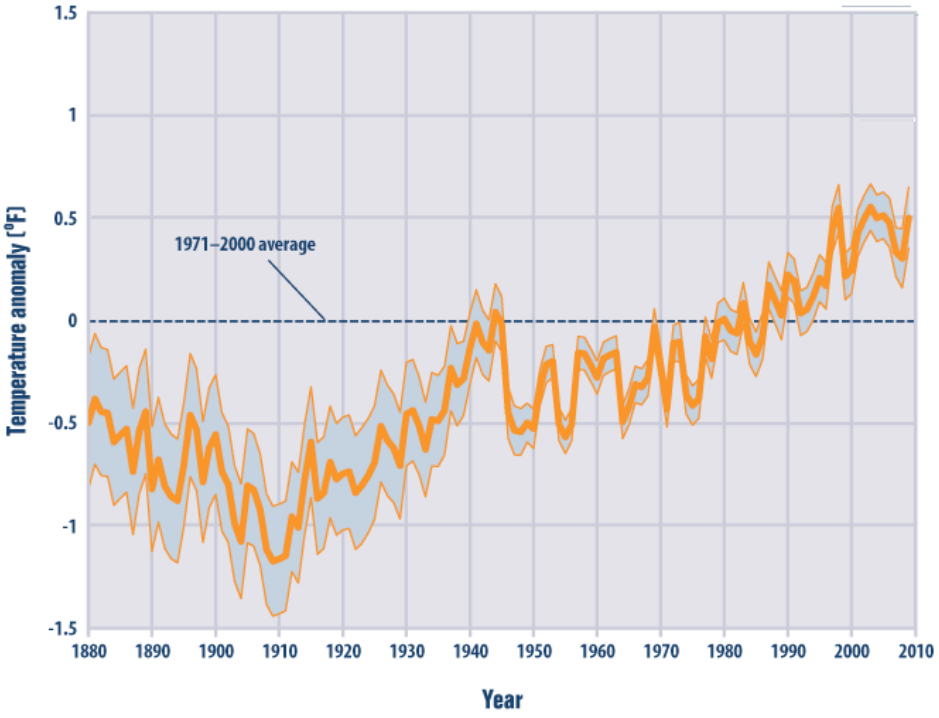
The "Blue Line"

Dr. Fletcher has produced animated fly-overs showing a contour line marking inundation that would occur with 1 m sea level rise. (See Getting Ready section.) The maps have an accuracy of roughly 30 cm. In this lesson, students will view these animations to see the portion of the islands that will fall below sea level if the sea rises the 1 m that is projected for end of this century.

As students will see from the blue-line maps, the low-lying areas near the ocean are extremely vulnerable to affects of rising seas, including increased threats from tsunamis and major storms. As Dr. Fletcher notes on the Blue Line website, "Don't think that waves will be rolling down the streets and reaching the blue line. More likely, lands lying below sea level in the future will be dry at low tide during arid summers. But they will have high water tables, standing pools of rainwater, and backed up storm drains when it rains and tides are high." (Fletcher 2008).

The other website listed under Getting Ready above (http://www.soest.hawaii.edu/coasts/data/) has beach erosion maps for some areas of the islands. There is also an animation of flooding in Waikīkī with a 1 m rise in sea level. Click on your island on the map and see what resources are available for your class.

Ocean Temperatures

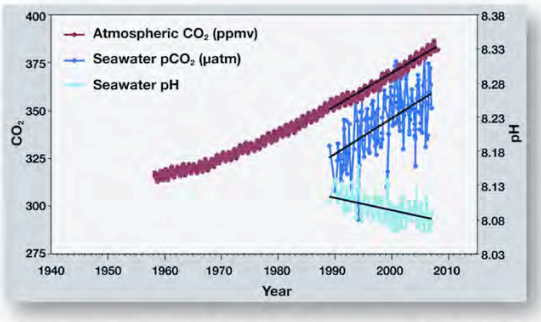


Graph courtesy of the Environmental Protection Agency, 2010

The graph above shows the change in average global sea surface temperatures since 1880. The average sea surface temperature from 1971- 2000 provides a baseline from which to measure change. The shaded area shows a range of values (EPA 2010). The average global sea surface temperature is rising. In Hawai‘i, scientists monitoring sea surface temperatures report that data from Station ALOHA, 62 miles (~100 km) north of Kahuku Point on O‘ahu, show an increase of 0.22° F (0.12° C) per decade, which is consistent with other estimates for the same latitudes in eastern North Pacific (Fletcher 2010). In this lesson, students will investigate local sea surface temperatures as well as the salinity and pH of the ocean. Students will collect salinity measurements along the coast to help identify areas where groundwater may be flowing into the ocean. When groundwater flows into the ocean there is often a temperature inversion, with cold, less saline water at the surface, and warm saltier water on the bottom.

Ocean Acidification

In previous lessons, students saw the correlation between rising levels of carbon dioxide in the atmosphere and rising temperatures. In this lesson, they will see another correlation: between rising carbon dioxide in the atmosphere and lowering of pH in the ocean. The implications for this lowered pH are described on one of the student readings that accompanies this lesson.



This graph shows the correlation between rising levels of carbon dioxide (CO_2) in the atmosphere at Mauna Loa with rising CO_2 levels in the nearby ocean at Station Aloha. As more CO_2 accumulates in the ocean, the pH of the ocean decreases. (Modified after R.A. Feely, Bulletin of the American Meteorological Society, July 2008)

Graph Courtesy of the Encyclopedia of Earth: http://www.eoearth.org/article/Ocean_acidification

By collecting data at a local beach, students will begin to see how climate change will affect their community. They will determine how projected changes in sea level will impact beach erosion and where the “blue line” in their community could be by the end of the century. They will also collect data on ocean pH and temperature as a baseline for the community.

See the Getting Ready section above with notes about timing the students’ beach study at low tide to ensure safety.

TEACHING SUGGESTIONS

Introducing the lesson

1. **Introduce the focus question for this lesson.**

   Focus Question: *How is climate change projected to affect shoreline communities in Hawai'i?*

   - Show students a meter stick and share with them that the projected sea level rise for Hawai'i is approximately 3.3 ft (1 m) by the end of this century.
   - Ask students to generate some initial ideas and questions about the potential affects of this sea level rise and add these to the K-W-L chart created in Lesson 1.

Part 1: The Blue Line

2. **Project the Blue Line Project animated fly-overs.**
   - Explain that the University of Hawai'i Blue Line Project created maps showing the effects of a 1 m rise in sea level on Maui, O'ahu and Kaua'i.
   - Show students an animated fly-over of one or more of these maps: http://www.soest.hawaii.edu/coasts/sealevel/index.html (see Getting Ready). Since there is no way to pause the animation, students will need to watch carefully and may need to view them more than once.

3. **Conduct a timed Think-Pair-Share activity.**
   - Use Google Earth to project aerial views of the shoreline in your community.
   - Display the following question on the board:
     - *How would the beach and areas near the beach in our community be affected by a 1 m rise in sea level?*
   - Ask students to stand up, puts their hands up in the air, and find a partner.
   - Once they find a partner, ask students to put their hands down (hands up indicates those who do not yet have a partner).
   - Give all of the pairs two minutes to look at the aerial view and think about the question posted on the board.
   - Assign one partner to go first (by a random indicator, such as the tallest, or the one whose birthday is closest to January 1, for example).

- Explain that student 1 has 30 timed seconds to answer the question on the board.
- Signal the end of 30 seconds and ask student 2 to answer the same question in 30 seconds.
- Signal the end of 30 seconds and ask students to thank their partner.
- Repeat with at least 2 more partners.
- Summarize students' responses on the board.

Part 2: Changing Shorelines

4. Distribute Student Reading 3.

- Go over **Part 1** of the Student Reading in class.
- Project the images of the beach profiles and discuss students' observations of how beaches change during winter and summer with changes in surf.
  - How does the beach change with the seasons or with high surf from storms?
  - How do seawalls affect the natural movement of sand? (Seawalls further exacerbate beach erosion by reflecting wave energy, producing turbulence at the interface and carrying sediment offshore with reflected waves.)

5. Go over Student Reading 3, Part 2.

- Discuss the beach photograph on page 80. What influences the shape of a beach (sand grain size, wave energy, and amount of sand available. Note that the photograph shows the difference in beach slope versus grain size, i.e., sand versus cobbles and boulders.)
- Review the diagram of a beach profile and the ratio relationship it depicts on page 76.
- If students are not familiar with ratios, introduce them to the concept.
- If desired, have them practice working with ratios. See interactive online ratio activities at: http://www.internet4classrooms.com/skill_builders/ratio_proportion_math_sixth_6th_grade.htm

6. Use a large scaled drawing of the shoreline retreat diagram to demonstrate the ratio relationship.

- Explain that the diagram on the Student Reading is not to scale and show students the scaled drawing prepared earlier (see Getting Ready).
- Have students demonstrate how knowing the L/D ratio allows us to project shoreline retreat with anticipated sea level rise. *Use the metric system for this demonstration to make the math easier for students.*
  - Have one student mark a 1 cm rise in sea level at D on the large diagram.

- Ask students how far the high tide mark would move inland (length of L) with a 1 cm rise in sea level at D. (Ratio of L/D = 100 so L would be 100 cm longer - shoreline retreats 100 cm.)
- Ask two students to show where the new high tide mark would be (use blue yarn to increase the length of L 100 cm or 1 m). If desired, raise the sea level at D another 1 cm and again show where the new high tide mark would be.

- Have students complete the math and review their answers. *With a ratio L/D = 100, how far inland would the new high tide mark be in the year 2100 if sea level rose 1 m?*

$$\frac{\text{100 m shoreline retreat}}{\text{1 m sea level rise}}$$

- *Using the ratio, calculate how far inland the high tide mark would retreat in a decade. Show your work.*
  1 m sea level rise (SLR) in 90 years = 0.011 m/yr (1.11 cm/yr) SLR
  0.011 m/yr x 10 yr = 0.11 m sea level rise in 10 yr x 100 = 11 m shoreline retreat per decade
  11 m x 90 yrs = 99 m (324.8 ft) shoreline retreat by 2100

- Explain that students will use the L/D ratio to collect some measurements at your local beach.

7. Distribute Student Reading 4 and explain that it provides background information for students' field study.

- Conduct a jigsaw activity with students in six groups. Have two groups assigned to each section of the reading:
  - Ocean Temperature
  - Ocean Acidity
  - Salinity
- Have students read their sections closely, underlining or highlighting key points. Circulate and assist as needed.
- Form groups of three with "experts" from each of the groups coming together to share what they learned.

Part 3: Collecting Data

8. Review Student Reading 4 and discuss key concepts.

- How much has the ocean temperature risen in Hawai'i?
- Why should we be concerned about the ocean temperature?
- What is pH and how is it changing in the oceans?

9. Divide the class into teams and set up the field study.

- Assign a data topic to each team and distribute the corresponding data sheets with clipboards:
  - Teams 1 & 2 - Beach Profile with Blue Line Projection
  - Teams 3 & 4 - Inventory and Map Below Blue Line Projection
  - Team 5 - Ocean Temperature, salinity and pH
- Ask teams to review their data sheets and collect the equipment they will need for the field study.
- Have students from each team share the type of data they will be collecting in the field with the rest of the class.

10. Collect data at the beach in your community.

- Take students to the beach, set up boundaries for the study, and discuss safety.
- Establish the time for all groups to complete their data collection.
- Show teams 1 - 4 how to use the GPS equipment to locate their landmarks.
- Have teams 1 - 4 document their findings with photographs.
- If possible, have students record video of their measurements. (Note that these segments can be edited into an introductory video to share with others in the lessons that follow.)
- Ask each team to guide the rest of the class through the procedure they followed.

NGSS:

Have students generate questions to clarify evidence they have gathered at this point in the unit.

Challenge them to begin constructing an argument, citing evidence gathered in the field and in readings, to support claims that changes to climate are affecting coral reefs and sea level in Hawai‘i.

Part 4: Summarizing

11. Ask students from each team to present their findings.

- Have students share photographs, data, and videotapes and discuss their findings.
- Be sure students understand what a mean or average is and have them calculate the mean for their data on temperature, pH, and salinity.
  - Should we collect data on pH and ocean temperature on more than one day? How often could we collect and record this data?
  - How should the data be archived as a baseline for future studies?
  - How will the projected sea level rise impact our community?
  - What might the impacts be on vegetation and structures below the “blue line”?
  - How will this projected shoreline retreat impact our community in planning for safety during tsunami warnings?
  - How should our community plan for sea level rise over time? Are there structures that need to be moved or rebuilt farther inland? Should the tsunami hazard zone be relocated? How far?

12. Summarize what students have learned and revisit the K-W-L chart.

- Have students post what they have learned and what they still wonder about on the K-W-L chart.

The beach profile measuring activity that students conduct in this lesson is adapted from Sandwatch: adapting to climate change and educating for sustainable development. This is a publication of UNESCO (see References).

Extending the Learning

- Have students map their beach during summer and winter months to see the natural movement of sand. If visiting the beach in winter, be sure to emphasize safety near the water. Have them collect data on ocean temperatures at regular intervals during the school year at the same time of day for each measurement.

- Encourage students to learn more about ocean acidification. The Center for Microbial Oceanography: Research and Education (C-More) from the University of Hawai'i has education kits that teachers can borrow, including a kit on ocean acidification. For more information go to: http://cmore.soest.hawaii.edu/education/teachers/science_kits/ocean_acid_kit.htm

- Have students check the following NOAA website to find out how much sea level has risen in your area: http://tidesandcurrents.noaa.gov/sltrends/sltrends.html

- Download the file: *A Framework for Climate Change Adaptation in Hawaii*. A collaborative effort of the Ocean Resources Management Plan Working Group with the assistance of the University of Hawaii, Center for Island Climate Adaptation and Policy. November 2009. http://hawaii.gov/dbedt/czm/ormp/reports/climate_change_adaptation_framework_final.pdf Copy select pages to share with students to supplement the discussion on how we plan for climate change in Hawai'i.

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UNESCO. "Sandwatch: Adapting to Climate Change and Educating for Sustainable Development." Paris. UNESCO. 2010. Accessed October 5, 2011. www.unesco.org/csi/sandwatch. (Note: This is a wonderful resource. However, the tsunami section mentions that low-lying coastal areas below 6 m (20 ft) in height may be flooded, and it is actually safer to say low-lying coastal areas below 100 feet may be flooded.)

U.S. Environmental Protection Agency. "Climate Change Indicators in the United States". Washington, D.C.: U.S. Environmental Protection Agency. 2010. Accessed October 23, 2010. *http://www.wwfblogs.org/climate/content/epa-climate-change-indicators-keyfindings-apr2010*

Student Reading 3:
Carbon Consequences – Changing Beaches

How is climate change projected to affect shoreline communities in Hawai'i?

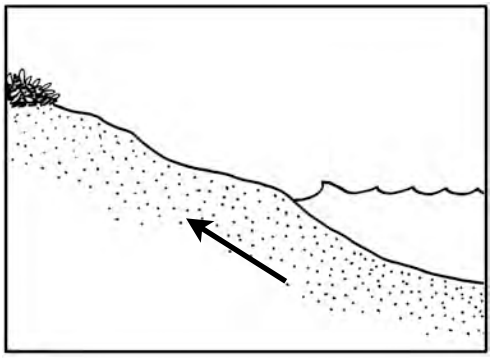
Part 1
Rising Sea Level

Scientists use data from satellites carrying altimeters to calculate how much sea level is rising on Earth. The rate of sea level change varies in different parts of the globe due to factors such as wind pushing the surface layer of the ocean, but the average global rise has been about 3.3 mm/yr. (0.13 in/yr) since 1993. This rate has been increasing due to melting ice and the warming of the ocean (Fletcher 2009). What does this mean for our future living on islands in the middle of the Pacific?

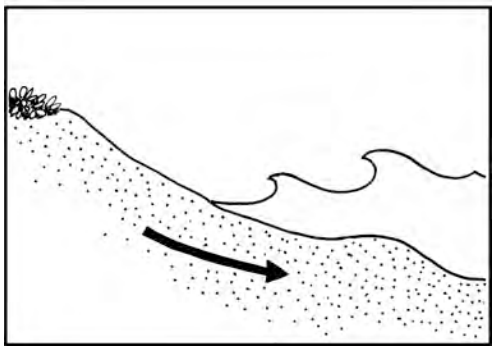
University of Hawai'i researcher, Dr. Charles Fletcher, projects a rise of approximately 1 m (3.3 ft) in sea level by the end of this century for Hawai'i (Fletcher, 2008). Dr. Fletcher predicts that the consequences of climate change and sea level rise for shoreline communities in Hawai'i will include flooding farther inland from ocean water, including tsunamis, eroding beaches, salt water getting into groundwater, and increased flooding due to heavy rainfall.

Eroding Beaches

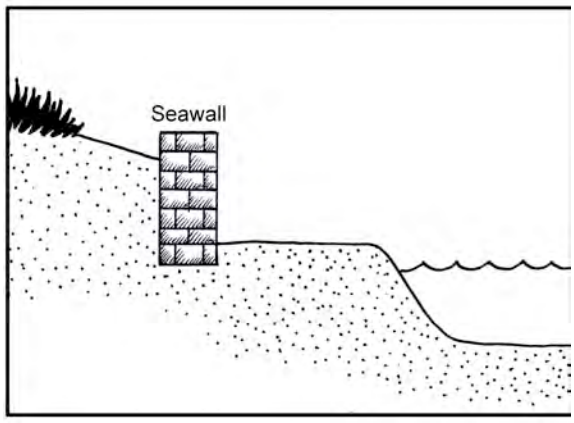
In this activity, we will investigate eroding beaches and how our shorelines may change. We know from visiting the beach during different times of the year and after major storms, that sand moves and beaches can change.

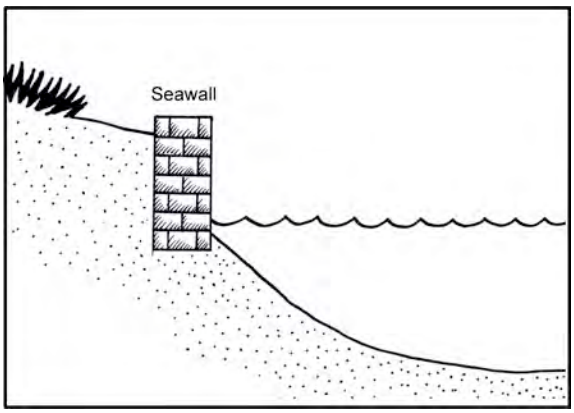


During kau wela (summer) season, the surf along north-facing shores dies down and the more gentle waves and wind gradually move the offshore sand toward the beach, building the sand up.



During ho'oilo (winter) season along north-facing shores, the surf rises and storms generate waves that take the sand away. The waves deposit the sand offshore. This deposit of offshore sand helps to break the force of the waves, which cuts down on beach erosion. This sand movement is a natural process.





What happens to the beach when we build a seawall in the sand?

The first picture is the beach in kau wela (summer) season.

The second picture shows the same beach in ho‘oilo (winter) when the surf picks up. Look at the level of the sea. What has happened to the beach? How does the seawall affect the natural movement of the sand during the seasons?

With sea level in Hawai‘i projected to be 1 m higher by the end of the century, how will this affect the beach in our community?

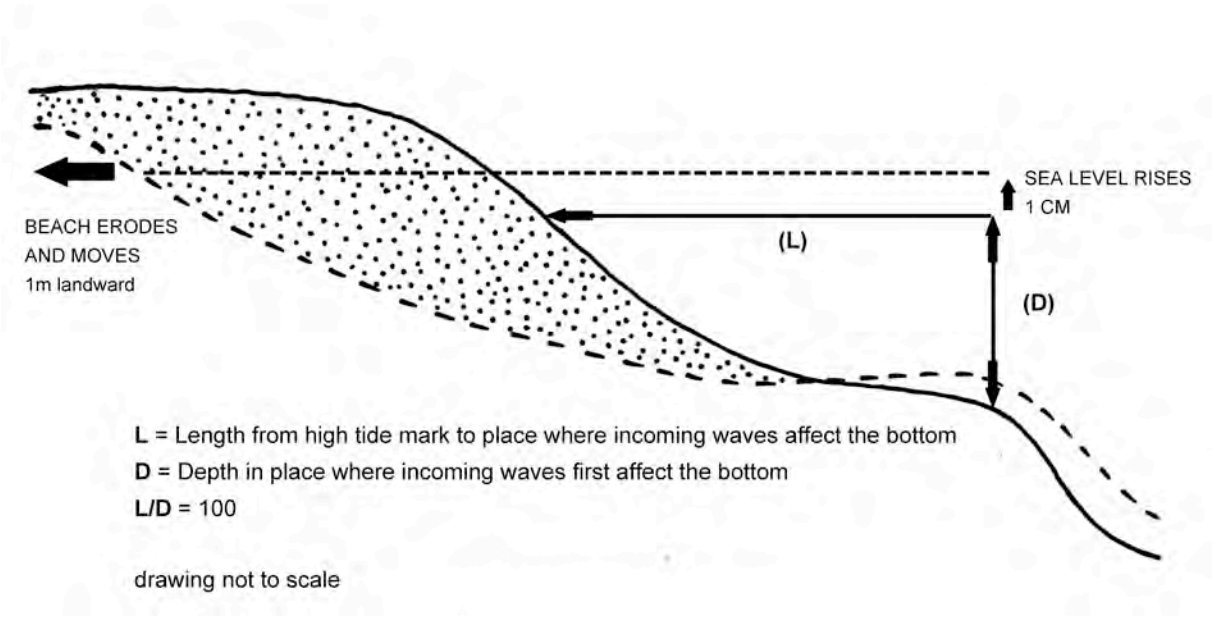
Part 2 - Estimating Shoreline Retreat with Rising Sea Level

It is possible to estimate the change in a beach with rising sea level.

➡ We can estimate where the new shoreline will be by studying the beach profile and using a ratio to compute the distance that the shoreline will retreat landward.

➡ The shape of a beach profile depends on the size of the sand grains, the amount of sand available, and the size of the waves.

➡ If the beach has coarse, large sand grains, the beach tends to be steep. If the sand grains on a beach are fine, the profile of the beach tends to be more gentle. What do you notice about the beach profiles in the photograph?



The diagram of a beach profile above shows an example of what can happen to the shoreline with sea level rise. In this example, for every 1 cm that the sea level rises, the shoreline retreats (beach erodes) 100 cm inland. In the diagram, D is the depth of the water where the incoming waves first affect the bottom. L is the length from the high tide mark on the beach to the place offshore where incoming waves first affect the bottom. For every 1 cm that the depth at D increases, the length of L increases 100 cm. This is a ratio relationship between the rate that the shoreline retreats landward and the rate that sea level rises. The ratio L/D is usually about 100. This ratio can vary though, to about 50 for steep beaches, and closer to 200 for more gently sloping beaches.

➡With a ratio L/D = 100, how far inland would the new high tide mark be in the year 2100 if sea level rose 1 m?

➡Using the ratio, calculate how far inland the high tide mark would move inland in a decade. Show your work.

Student Data Sheets 1 and 2 will guide you to investigate how the beach in our community could change as sea level rises.

Student Reading 4: Carbon Consequences – Changing Oceans

Ocean Temperature

University of Hawai'i scientists are measuring sea surface temperatures at stations around the Hawaiian Islands. Data from Station ALOHA, 62 miles (~100 km) north of Kahuku Point on O'ahu, shows an increase in sea surface temperature of 0.22°F per decade (0.12°C per decade). This is similar to other estimates for temperatures at the same latitudes in the eastern north Pacific.

A change in sea surface temperature of less than a degree F in a decade does not seem like much. Is this change something we should be concerned about? Here are some things to think about.

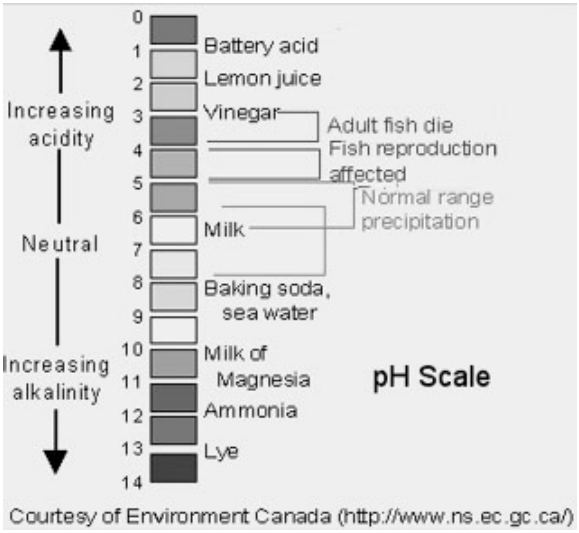
As ocean temperatures rise...

- Corals and other marine life not adapted to higher temperatures can be harmed.
- Currents can be affected and nutrients from deep ocean waters may not circulate as well.

- Climate can be affected by changing currents and wind patterns.
- The intensity and frequency of storms, including hurricanes, can increase.
- Seawater will absorb less CO_2, increasing global warming.

Ocean Acidity

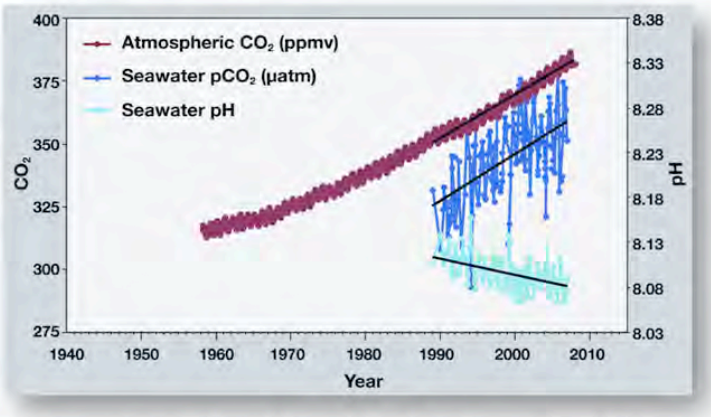
As we have seen from our study of the carbon cycle, the amount of CO_2 in the atmosphere is increasing from human activities, primarily from burning fossil fuels. Some of the CO_2 is staying in the atmosphere, warming the planet. Approximately one-third of the CO_2 added to the atmosphere by burning fossil fuels is absorbed by the oceans. When the oceans absorb CO_2, carbonic acid is formed, making the water more acidic. As the water becomes more acidic, there is less calcium carbonate available. Calcium carbonate is what many marine organisms need to build skeletons and shells.



Courtesy of Environment Canada (http://www.ns.ec.gc.ca/)

We measure acidity using a **pH scale**. The pH of a liquid is a measure of how acidic or alkaline it is. It is measured on a scale of 1 – 14, where 7 is neutral. Numbers below 7 are acidic (like lemon juice), and numbers above 7 are alkaline (like soap). It is a logarithmic scale, so for each number on the scale, there is a ten-fold change in acidity. For example, vinegar with a pH of 2 is ten times more

acidic then grapefruit (pH of 3), and 100 times more acidic than tomato juice (pH of 4). What is the pH of sea water? (~8.2)



This graph shows the correlation between rising levels of carbon dioxide (CO_2) in the atmosphere at Mauna Loa with rising CO_2 levels in the nearby ocean at Station Aloha. As more CO_2 accumulates in the ocean, the pH of the ocean decreases. (Modified after R.A. Feely, Bulletin of the American Meteorological Society, July 2008)

Graph Courtesy of the Encyclopedia of Earth: http://www.eoearth.org/article/Ocean_acidification

We have seen from the data collected on top of Manua Loa that CO_2 is rising in the atmosphere. Data from the ocean at Station Aloha show that the level of CO_2 in the ocean has risen too. What does the graph show is happening to the pH of the seawater?

Salinity

Salinity is the total amount of dissolved material (salts) in seawater. The average salinity of ocean water is 35 ppt (parts per thousand). The salinity of the water is affected by the amount of rainfall and evaporation. And, in nearshore waters, salinity is affected by streams and inflow of groundwater. You will be collecting salinity measurements along the coast to help identify areas where groundwater may be flowing into the ocean. When groundwater flows into the ocean there is often a temperature inversion, with cold, less saline water at the surface, and warm saltier water on the bottom. **Student Data Sheet 3** will guide you to investigate how to obtain data about ocean temperature, salinity and acidity of the seawater in our community.

To learn more about the effects of climate change on islands, including impacts on coral reefs, go to Centers for Ocean Science Education Excellence website and select Climate Change. Then select the "Try It - Climate Change": http://www1.coseecoastaltrends.net/modules/coral_reefs_and_climate_change/what_is_climate_change/

➡ Write a paragraph to summarize how climate change will affect islands.

TEAM #_____

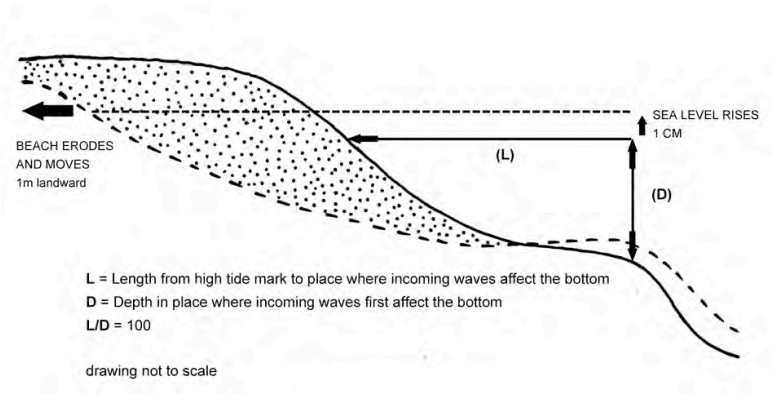
DATA SHEET 1: BEACH PROFILES

TEAM MEMBER'S NAMES:

_____

FIELD STUDY DATE_____WEATHER CONDITIONS_____

TIDE: (HIGH, MEDIUM, OR LOW)_____TIME OF DAY_____



Researchers have found that on average, for every 1 cm rise in sea level the shoreline (high tide mark) will move landward 100 times that amount. The ratio is L/D = 100. If your beach has an average profile, (not too gentle or too steep) use your calculations from Student Reading 1, assuming a 1 m rise in sea level by 2100, and follow the procedure below.

Take Inventory: What does the beach in your community look like?

☐ coarse sand	☐ fine sand
☐ a steep profile	☐ a gentle profile
☐ seasonal high surf	☐ usually has no surf
☐ has strong currents	☐ does not have strong currents

The L/D ratio can vary to about 50 for steep beaches with coarse sand, and closer to 200 for more gently sloping beaches with fine sand. If your beach fits either of these descriptions, calculate the level of shoreline retreat using a L/D ratio of 50 or 200.

Materials
- ✓ meter tape measure
- ✓ paper and markers (to make signs)
- ✓ clipboards and pencils
- ✓ digital camera
- ✓ video camera (optional)
- ✓ drinking water

Procedure

At the beach:

- Work with the other team that has Data Sheet 1. Each team should run separate meter tape lines in different areas of the beach within the shoreline boundaries established by your teacher.
- Locate the present high tide line.

- Using a meter tape running perpendicular to the shoreline, measure from the high tide mark to the distance that the beach would retreat landward in 10 years. Position a student there with a 10-year sign and take a photograph.
- If available, use GPS to record the exact location of your sign. If using only photographs, follow the Taking Photographs tips below.
- Repeat the procedure for marking the 50-year and 90-year projected shoreline retreats.

Taking Photographs

- Photographs should include a frame of reference so that the mark can be located in the future.
- If possible, frame the person holding the sign with a landmark (natural or human-made feature) on either side of the photograph.
- Measure the distance from the person holding the sign to a known landmark and record the distance below.

10-Year Shoreline_____
50-Year Shoreline_____
90-Year Shoreline_____

Sharing

- If a video camera is available, select people from your team to record your shoreline signs and explain what they mean. Include footage of the present beach and structures and features that would be affected by sea level rise.
- Share your markers with the other teams and explain how you calculated them.

Reflections

Work with your team to write a reflection about your findings. You may want to record these reflections on a videotape to share with others.

TEAM #_____

DATA SHEET 2: BEACH INVENTORY

TEAM MEMBER'S NAMES:

_____

FIELD STUDY DATE_____WEATHER CONDITIONS_____

TIDE: (HIGH, MEDIUM, OR LOW)_____TIME OF DAY_____

Two teams will each map a portion of the present beach and the area below the new "blue line"--the projected high tide mark by the year 2100 due to sea level rise.

Materials
- ✓ meter tape measure
- ✓ blue yarn
- ✓ digital camera
- ✓ 5 sheets of paper and pencils for mapping
- ✓ clipboards
- ✓ compass
- ✓ drinking water

Procedure

Part 1 - Measuring

- Find the high tide mark on the beach.
- Facing ma uka on this mark, measure the width of the portion of the beach your team is to map (determined by your teacher).
- Find the center of this measurement. Hold a blank sheet of paper in the landscape orientation. This sheet will be your field map.
- Fold your map paper in half and then open it and place on a clipboard. The fold represents the center of your study area.
- Using a compass, locate north and draw a north arrow on your map
- Develop a scale for your map, such as 1 cm = 1 m. Write the scale at the bottom of the map.

Part 2 - Taking inventory - Locate, measure, and map

- Locate the features on the beach and check them off in the list below.
- From the center point on your map at the high tide mark, measure the distance to features and place symbols for each feature on your map.
- Be sure to create a key for the symbols that you use and draw this key on the map.

☐ seawalls

☐ native vegetation

☐ structures (hale waʻa, beach houses, roads, parking lots)

☐ cultural or other significant sites

☐ other_____

Part 3 - Drawing the "Blue Line"

- Follow Data 1 teams as they move ma uka. If needed, use additional sheets of paper to create map sections to keep your map to scale.
- When Data 1 teams mark the 2100 shoreline, use blue yarn to connect their two high water markers. This line represents the projected new high tide line with a 1 m rise in sea level.
- Add the blue line to your map and take a photograph of students holding this blue line. See Taking Photograph tips below. If GPS is available, record coordinates for the blue line.
- Make note of all of the structures and vegetation that fall below the blue line and include them on your map sections. Take photographs of the features.

Taking Photographs

- Photographs should include a frame of reference so that the mark can be located in the future.
- If possible, frame the students holding the blue line with a landmark (natural or human-made feature) on either side of the photograph.

Sharing

- If a video camera is available, select people from your team to be the spokespeople to describe the structures and landmarks that would be affected by sea level rise below the blue line.
- Share your maps with the other teams and point out the structures and landmarks below the blue line.

Reflections

Work with your team to write a reflection about your findings. You may want to record these reflections on a videotape to share with others.

Team #_____ Data Sheet 3: pH, Salinity & Temperature

Team Member's Names _____

Date_____ **Weather Conditions**_____

Tide: (high, medium, or low)_____**Time of Day**_____

Your team will be measuring the following factors to establish a baseline for your community:

- **pH** - The degree of acidity or alkalinity of the seawater. For most marine organisms, a pH of 6.5 – 8.5 is best. If pH falls below 5, fish reproduction is affected; below 4.2 fish will die.
- **Temperature** - Corals thrive in water temperatures 73 - 84° F (23 - 29° C). Coral bleaching can occur if the temperature rises by only 1 – 2 degrees Celsius above normal levels.
- **Salinity** - The average salinity of ocean water is 35 ppt. In the nearshore water, the salinity of the water will be affected by the inflow of groundwater as well as by the amount of rainfall and evaporation.

Water Temperature, pH and Salinity

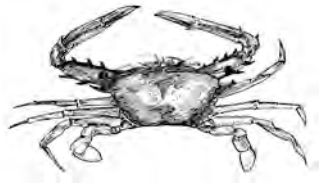
Procedure

Conduct the tests below at three evenly spaced sites in your field study area. Then compute the mean (average).

1. Collect a surface water sample.
2. Using a thermometer, immediately measure the temperature. Record once the mercury in the thermometer stops moving.
3. Using a pH test kit, follow the directions to measure the pH of the water sample.
4. Check with your teacher or adult leader about surf conditions before collecting water at depth. If you are able to proceed, use a collection bottle, extend it below surface a full arm's length. Open the bottle under water and collect water at depth.
5. Using a thermometer, measure the temperature of the deeper water. Record.
6. Using a hydrometer, measure the salinity at the surface and at depth. Record.

Materials
- ✓ pH test kit
- ✓ thermometers
- ✓ hydrometers
- ✓ water collection bottle
- ✓ clipboards
- ✓ pencils

	Site 1	Site 2	Site 3	Mean
Temperature (Surface)				
Temperature (Depth)				
pH				
Salinity				



Reflections

How do your findings compare to the range of pH and temperature that is best for marine life? What do you think future trends will be? Explain your thinking.

How will you archive your data so that students can compare it to readings they measure in the future?

VOCABULARY PRACTICE 3

NAME_____ **DATE**_____

1. Write a definition for each of the following terms:

Ocean acidification:

pH:

Ratio:

Salinity:

Tsunami:

2. Use these vocabulary in a paragraph to summarize what you have learned in this investigation about our changing ocean and beaches.

Hō'ailona (Signs in Nature)

How are changes in local weather, ocean conditions, and in plants and animals clues to climate change?

Activity at a Glance

Student teams interview local fishers and kūpuna about changes they have observed in local weather, ocean conditions, and plants and animals over time. Students complete interviews, compile their findings, and correspond with schools in other Pacific locations to share information and images about climate change in Hawai'i.

Key Concepts

- Changes in Hawaiian weather (air temperature, rainfall and wind patterns) and ocean conditions (sea surface temperature, sea level, ocean pH, and currents) over time provide clues to understanding how our climate and sea level are changing.

- Changes in plants and animals such as coral bleaching or altered timing of marine life cycles provide clues to changing ocean conditions.

Skills

Collaborating, researching, analyzing, inferring, listening, communicating in writing and orally

Assessment

Students:

- Collaborate with a group to collect data about local ocean, shoreline, or weather conditions.

- Complete an interview with kūpuna, fisher or other community member familiar with ocean or weather conditions to record observed changes.

- Write a team letter to students in a school in the Pacific to share local concerns and images about climate change in Hawai'i and request information about climate change in the recipient's location.

Hawai'i State Standard Benchmarks

Science 1: The Scientific Process - Scientific Inquiry

- **SC.6.1.2** Use appropriate tools, equipment and techniques safely to collect, display, and analyze data.

Science 2: Nature of Science - Science, Technology and Society

- **SC.6.2.1** Explain how technology has an impact on society and science.

Common Core Standards

Language Arts: Production and Distribution of Writing

- **W.6.6** Use technology, including the Internet, to produce and publish writing as well as to interact and collaborate with others.

Nā Honua Mauli Ola

'Ike Pilina - Relationship Pathway

- **NHMO.1.3** Interact with kūpuna in a loving and respectful way

'Ike Honua - Sense of Place Pathway

- **NHMO.8.1** Be keen observers of their natural environment

Suggested Timeframe

Three to four 45-50-minute class periods

Day 1: Introduction and Student Reading 5

Day 2: Preparing for interviews - Learning Log 5

Days 3 - 4: Conducting interviews (outside of class); sharing and summarizing; Learning Log 6

Materials

Provided

- Learning Log 5: Learning from Kūpuna
- Interview Forms
- Student Reading 5: Hōʻailona
- Learning Log 6: Hōʻailona Graphic Organizer

For You to Provide

- Digital camera
- Video camera, microphone and tripod (optional)
- Audio tape recorder (optional)

Getting Ready

- ✓ Make a copy of the the Learning Logs and Student Reading for each student.
- ✓ Copy a set of Interview Forms for each interview to be conducted.
- ✓ Preview the following website for information to enhance this lesson:
  - ✓ Center for Ocean Sciences Education Excellence (COSEE) website: Coral Reefs and Climate Change: http://www1.coseecoastaltrends.net/modules/coral_reefs_and_climate_change/what_is_climate_change/

Vocabulary

Base Flow: in this context, streamflow from groundwater sources during dry weather conditions

Hōʻailona: signs in nature

Zooxanthellae: the algae that live within the tissues of coral polyps and produce food for the coral through photosynthesis

Teacher Background Information

In addition to the background provided in the Student Reading, there are three documents in the Appendix to supplement the information provided in the unit. These documents are:

Dudley, Walter. "Tsunami Survivor Interview Protocol - High-quality Video Interviews." - This document will provide helpful tips for videotaping interviews.

EPA. "Climate Change Indicators in the United States." - The Indicators summarize key clues to climate change and include some of the graphs that have been provided in this unit.

Fletcher, Charles H. "Hawai'i's Changing Climate Briefing Sheet 2010." - This briefing sheet summarizes changes to Hawai'i's climate including changes in air temperature, rainfall and stream flow, storm intensity, sea level, sea surface temperatures, and ocean acidification.

Teaching Suggestions

Introducing the lesson

1. **Pose the focus question for this lesson to students and ask them to share their ideas.**

   Focus Question: *How are changes in local weather, ocean conditions, and in plants and animals clues to climate change?*

   - Review findings from Lesson 3 and discuss and record any changes in local conditions that students have heard about or noticed.
   - Explain that change over time is difficult to perceive, especially in young people.

2. **Introduce the idea of interviewing people in the community to shed light on changes over time.**
   - Explain that students will have an opportunity to interview kūpuna (elders) and others in the community about climate change in Hawai'i.

Part 1: Interviewing Kūpuna About Hō'ailona

3. **Distribute Student Reading 5 and read and discuss the Introduction together as class.**
   - Conduct a jigsaw activity to help the students understand the Reading. Divide the class into five groups based on each subheading in the Reading.
   - Circulate and assist students. Ask them to underline or highlight the key points in their sections of the text.
   - Have students from the different groups gather in teams of five with an "expert" from each of the content areas. Ask each "expert" to share what was read with the other students. Have students jot down some questions that the reading stimulates for them.
   - Discuss the reading.

- What are the hō‘ailona--signs in nature that are clues to climate change? List these on the board or chart paper.
- What kinds of questions should we ask kūpuna in our community about hō‘ailona?
- What makes a good interview question? (open-ended questions that elicit more than a yes/no response; questions that target content that will help to answer the larger questions)

- Distribute **Learning Log 5** and ask students to each generate two potential interview questions.

4. Prepare for interviews.

- Discuss how the class would like to proceed with interviews.
  - Who should we ask to interview in our community? Suggest possible sources of knowledge such as kūpuna, scientists, lifeguards, meteorologists, or fishers.
  - Should we conduct interviews in teams or here at school with the entire class?
  - If interviewees are agreeable to being videotaped, where will the interviews be conducted?
  - How should we divide the tasks of setting up interviews, recording them, and editing the final product?
- Project the **Interview Archive** form that lists tasks to be completed.
- Divide up tasks for conducting the interviews, set up a schedule, and post the form in the classroom.

If your school has a technology coordinator or if a parent is willing to assist, consider asking for help in conducting and editing videos. Be sure to have students practice using cameras and audio equipment before conducting interviews.

5. Prepare interview questionnaires.

- Form pairs of students and have the pairs exchange their **Learning Log 5** sheets and conduct a peer review of the interview questions.
- Ask students to edit the questions, fine-tune them as needed, and select the questions they would like to include on a questionnaire.
- If the class is working in teams, have teams meet and develop their questionnaires. If working as a whole class, have the class select questions and develop a questionnaire.

6. Review the interview forms.

- Project the **Interview Request Form** for students to review.
- Have students send the form to potential interviewees along with their questionnaires.
- Show students the **Release Forms** to be signed by interviewees. Explain that these releases are to ensure that the interviewees agree to

have video or audio tapes of their interviews or notes and pictures from their interviews shared on the project website.

7. Conduct and edit the interviews.

- If students are conducting interviews in the community, have them conduct a practice interview with classmates and critique the results.
- Monitor the scheduling and the proper use and return of equipment.
- If interviews are being conducted in class, review the roles that students will play [setting up interviews (lighting, background, etc.) camera operator, audio monitor, interviewers, editors].
- If students need assistance with video editing, ask a parent or technology coordinator to assist.

Part 2: Summarizing and Sharing

8. Complete interviews and review what has been learned.

- Ask students to send copies of videotaped interviews, transcripts of audio tapes, or notes for the interviewee to review and approve.
- Have students send mahalo notes to all who were interviewed and invite the interviewees to the hō‘ike (exhibit) at the end of the unit.
- When interviews are complete, review them with the class.
- Ask students to take notes from each interview and record what's important and interesting on **Learning Log 5.**

9. Distribute Learning Log 6 and review it with students.

- Explain that the graphic organizer is a way to summarize clues to climate change that students have been discovering in this unit.
- Ask students to review the Student Readings and their Learning Logs and complete the graphic organizer as homework.
- Review their work and check for areas that need further exploration to gain understanding.

10. Correspond with students in the Pacific.

- Have the class decide which edited video and/or audio tapes or written summaries and photographs to share with students in other parts of the Pacific.
- Ask students to write letters to send to students. Have them use their notes from **Learning Log 6** to help organize the main points they want to address in their letters. Discuss elements to include in letters, such as:
  - Summarizing what they have learned about climate change in Hawai‘i, including data, photographs or video from their field study in Lesson 3.

NGSS:

Ask students to continue constructing an argument, citing evidence gathered in the field and in readings, to support claims that changes to climate are affecting coral reefs and sea level in Hawai‘i. See websites listed at the end of this lesson for students to research.

Provide feedback on writing and have students revise to improve their work and express their deepening understanding.

    - Asking questions to encourage a reply from students in another location.
- Have students in each team combine their thoughts to compose a group letter to one of the classes on the list provided.

NOTE: To correspond with schools in Marjuro, Micronesia, contact Mark Stege at the Marshall Islands High School. Mark has been field testing Kai E'e lessons with his students and will help connect you to students in the Marshall Islands. Contact: markhstege@gmail.com. To correspond with schools in Alaska, contact Kathy Bertram at the University of Alaska. Kathy is the University of Alaska K-12 Outreach Director. Contact: kaberrybertram@alaska.edu

Extending the Learning

- Have students play a "Jeopardy" game to summarize what they have learned so far in the unit. Student teams could help design the game by selecting a category for which to develop questions and answers: Carbon Cycle, Ocean Conditions, Greenhouse Effect, Melting Ice, Weather and Climate.

- Show the video, *Micronesia's Changing Climate* by MCT Our Micronesia to students. The 30-minute program focuses on steps that communities in Micronesia are taking to reduce the potential effects of climate change. The video can be viewed online at: http://player.vimeo.com/video/31462831?autoplay=1

- Have students locate Wales, Alaska, which is the western-most town in the U.S., on a map. Show the video created by students in Wales and ask your students to take notes. The video is available from: Geophysics Institute, University of Alaska Fairbanks: Multimedia presentations about climate change in Alaska: http://arcticclimatemodeling.org/multimedia.html. Under Presentations, click on *Survival in a Changing Climate* - video by students of Kingikmiut School in Wales, Alaska. (Note: the video is divided into section which may take awhile to download.)
    - Discuss students' reactions to the video.
        - What did the elders share about changes in climate conditions in the Wales community?
        - How are the challenges that Wales faces different from our community? How are they similar?
        - Why is it important to honor our kūpuna and look to them for guidance?

- With students working in pairs or as a whole class, view the Center for Ocean Sciences Education Excellence website: Coral Reefs and Climate Change: http://www1.coseecoastaltrends.net/modules/coral_reefs_and_climate_change/get_started/
  - Scroll down to the Quick Links—Interactive Try Its and select Try It – Climate Change.
  - Select the various threats to reefs with climate change:
    - increased ocean temperatures
    - ocean acidification
    - sea level rise, and
    - increased storm intensity and frequency.
  - Have students describe the changes they see on the island and reef as they view the changes to images and the text with each threat.

- Have students look for the clues to climate change on the EPA interactive webpage for kids, A Student's Guide to Global Climate Change: http://www.epa.gov/climatechange/kids/scientists/clues.html

- Challenge students to research ways that we can adapt to climate change as we plan for the future. On the EPA's site: A Student's Guide to Global Climate Change, select the "Be a Part of the Solution" tab and click on "Preparing for the Future." http://www.epa.gov/climatechange/kids/solutions/prepare/index.html

- Have students explore videos about climate change created by schools around the Pacific. See: http://www.teachersdomain.org/special/pacific/

References

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Nakuina, Moses Kuaea. *The Wind Gourd of La'amaomao*. Honolulu: Kalamakū Press. Revised Edition. 2005.

U.S. Environmental Protection Agency. "Climate Change Indicators in the United States." 2010. Accessed October 23, 2010. *http://www.wwfblogs.org/climate/content/epa-climate-change-indicators-keyfindings-apr2010*

Interview Request Form

Aloha,

Our class is learning about climate change and how it may affect our community. We are requesting to interview you about any changes you may have observed in local weather, ocean conditions, or in plants and animals over time. We appreciate your kōkua.

Name: _____

Contact Information: (Please check box for preferred way to reach you.)

☐ Address _____

☐ Phone Number _____Best time to call?_____

☐ E-mail _____

We will be conducting interviews during these dates:

_____

Please let us know which dates and times you would prefer:

☐ Preferred Dates _____

☐ Preferred Times _____

☐ Preferred Location _____

Please return this form to:

Mahalo Nui Loa!

Form adapted from Pacific Tsunami Museum, Hilo, HI.

INTERVIEW ARCHIVES

Interview Processing Sheet

Interviewee Name_____

Address_____

Phone Number(s) _____

Method of Interview

- ☐ Videotaped
- ☐ Audio Recording
- ☐ Written Notes

✓	Task	Date Completed
	Requested interview (Sent letter, Interview Request Form, and Questionnaire)	
	Confirmed Appointment for Interview Date of Interview_____ Location _____	
	Interview Completed, Release Form signed, and Notes, Transcription, or Videotape submitted	
	Mahalo letter sent with Notes, Transcription or Videotape for interviewee to review	
	Follow-up with interviewee completed and any corrections made	
	File created with all documents for interview	
	Backup of video and audio recordings completed for files	

Form adapted from Pacific Tsunami Museum, Hilo, HI

Kai E‘e Project

Oral/Video Tape Release Form

I, _____(**interviewee**), hereby give, grant, assign, forever to the Kai E‘e Project, as a donation, all my rights, title and interest in and to the recorded conversations made by me and

_____(**interviewer**), as further described below, and any written summaries or transcripts or copies thereof and any documentation, materials and things accompanying the recordings, for use and disposition by the Kai E‘e Project or its successors and assign in any lawful way including publication, except as specified below, if any:

The **audio/video** tape-recorded material is further described as follows:

Number of tapes: _____ **Date(s)** recorded: _____ **Place**:_____

Length of interview: _____ **Camera crew**:_____

Event(s)/Location(s): _____

Topics:_____

_____

Signed: _____ **Date:** _____
(interviewee)

Interviewee Address:_____

_____

Signed: _____ **Date:** _____
(interviewer)

For Project and School Reference Only
Interview No. __ Object ID No. __

Form adapted from Pacific Tsunami Museum, Hilo, HI.

LEARNING LOG 5: LEARNING FROM KŪPUNA

NAME_____ **DATE**_____

- ➡ Write two interview questions for a kūpuna, fisher, or someone who you believe has knowledge of how weather and ocean conditions, or marine plants and animals have changed over time.
- ➡ Share the questions with the class and work together to create a questionnaire using the best questions for your interviews.

QUESTIONS

1.

2.

NOTES FROM INTERVIEWS

When all teams have completed their interviews, listen carefully and take notes of the most interesting and important information that helps you understand changes over time.

What's Interesting...	What's Important...

Student Reading 5
Hōʻailona – Signs in Nature

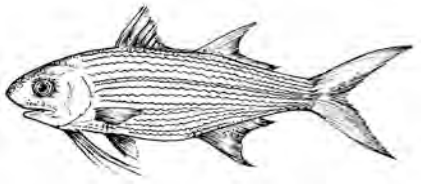
Introduction
Pākaʻa is known in Hawaiʻi as the keeper of the calabash of winds. He inherited this calabash from his mother, Laʻamaomao. As the keeper of this special calabash, Pākaʻa could call upon the winds for help as he needed them, just by calling each wind by name. This was no easy feat, as there are hundreds of different winds. Some say there are 260 winds for the island of Kahoʻolawe alone.

In old Hawaiʻi, people knew the winds of their islands and channels, recognizing the subtle changes in winds that arrived from different places in the sea, carrying characteristic fragrances and tempos. They named the different winds on each island for their characteristics. For example, there is the moaniʻala wind that is fragrant with the scent of hala wafting out to sea in Puna. Hilo kūpuna know the misty rain as kanilehua (the rain that makes lehua flowers rustle), and old-timers in Hilo and Hāna both refer to a rain that makes everything look white as ua kea. In Kekaha, Kauaʻi, there is a wind known as ʻōlau-niu, a coconut-leaf piercing wind.

Kūpuna in Waiʻanae know the pleasant gentle trade winds as kaiāulu (Nakuina 2005). Being in touch with the subtle changes in nature is a skill that many of our kūpuna possess. We look to them for guidance as we seek to understand changes in weather patterns and marine life in Hawaiʻi.

Today there are many clues that tell us our climate is changing. We know that our surface temperatures and rainfall are changing. We also know that air temperatures and rainfall depend on the winds that travel over the ocean and reach our shores. What we don't know for certain is how these wind patterns may be changing, if at all. Scientists are studying climate models to learn more about changes in the winds. When you interview kūpuna, see if they have noticed changes in the winds.

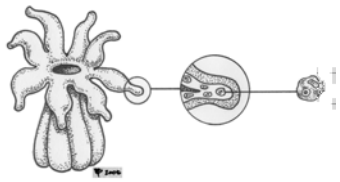
Changes in Fish Behavior



When marine plants and animals show signs of change, it may be a clue to a change in our climate. Some local fishers note that the Hawaiian moon calendar from 1922 showed moi leaving to spawn from May to September. Today moi are spawning one month later, from June to October. Other fishers will tell you that they used to fish for ʻoama (young weke or goatfish) near the shore in August. Today they fish for them a month later, in September. When you interview kūpuna or others, find out what kinds of changes they have observed in marine life.

Coral Bleaching

There are also times when corals provide us with a clue to changes in the ocean. Have you ever been snorkeling and noticed part of the coral is white (looking bleached out)? This "bleaching"is actually the loss of zooxanthellae--the algae that live within the tissues of the coral polyps and produce food for the coral through photosynthesis.



Since corals thrive in a narrow band of warm water temperatures, from about 77° F to 84° F (25° C to 29° C), even a slight rise in ocean temperatures can harm them. This is especially noticeable in El Niño years when our ocean temperatures are warmer. El Niño are warm surface currents that occur every three to eight years in the Pacific. If conditions are right in Hawai'i, such as warm temperatures and low winds in bays and lagoons, there can be large-scale bleaching of corals like there was in the late summer of 1996 and again in 2002 (Jokiel 2004). Ask people in your community if they have observed coral bleaching. To learn more, go to the Reef Check Hawai'i webpage: http://www.reefcheckhawaii.org/eyesofthereefBleach.htm

The data related to climate change below are from Hawai'i's Changing Climate Briefing Sheet 2010 *by Dr. Chip Fletcher, Department of Geology and Geophysics, SOEST, University of Hawai'i.*

Air Temperature

You may not have noticed, but Hawai'i is getting warmer. Over the past 30 years, scientists have collected data that show an increase of about 0.3° F (0.16° C) per decade. If we continue to warm at this rate, how much of an increase will we see by the end of this century? Why is this a problem?

Rainfall and Streamflow

Hawaiians have many different names for rains as well as winds. A chilly rain is kili hau, a rainfall with large drops is ua hekili, and a rainbow-hued rain is ua koko. When you interview kūpuna, ask if they have noticed any changes in the rains. Scientists have collected rainfall data over the last 20 years that show rainfall in Hawai'i has steadily declined about 15%. Some of the rain that does not runoff to the ocean, seeps into the groundwater. This is the water that feeds the streams in between rains. The streamflow at this time between rains is the base flow. Scientists have found that since the early 1940s, the base flow of streams around the state has declined.

Storm Intensity

In Hawaiian, a heavy downpour is ua lanipili. One thing you often hear about with climate change is that storms are becoming more intense. In Hawai'i, the intensity of storms is increasing even though our rainfall is decreasing. The very heaviest rainfall in the Islands has increased about 12% between 1958 and 2007. These downpours are the kinds of storms that cause mudslides, flash floods, and road closures. Find out what people in your community have observed about changes in storm intensity.

These hō'ailona are clues to changes that will affect our lives in Hawai'i. How we plan for climate change is going to be vital to our future. In the next lesson, we will explore ways to reduce our carbon emissions to help slow the process of climate change and plan for ways to adapt to the winds of change to come.

Learning Log 6:
Hōʻailona – Graphic Organizer

Name_____ **Date**_____

Take notes from the Student Readings and Learning Logs in this lesson and from the rest of the unit to summarize the clues to Hawai'i's changing climate. Note whether some of these clues are things that are increasing or decreasing and the rate of change, if it is known. This organizer will help you to prepare for the hōʻike (exhibit) at the end of the unit.

Carbon Dioxide in the Atmosphere

Rainfall and Streamflow

Air Temperature

Coral Bleaching

Hawai'i's Changing Climate

Changes in Marine Animals

Sea Surface Temperatures

Ocean Acidity

Sea Level

ENERGIZED!

How do we change the way we harness and use energy to reduce our carbon footprint in Hawai'i?

ACTIVITY AT A GLANCE

Students calculate their own carbon footprints and then collaborate in teams to conduct research into an alternative energy source that could reduce our carbon emissions in Hawai'i. They begin developing presentations on their alternative energy source for the hō'ike (exhibit) at the end of the unit where they will summarize their findings and share them with the community.

KEY CONCEPTS

- Decisions we make about our lifestyles can reduce our carbon footprints.
- The energy needs of society are influenced by ever-changing technologies, some of which can lead to reduced carbon emissions.
- Developing and utilizing different alternative energy sources can help to reduce our carbon footprints and slow the process of climate change and sea level rise.

SKILLS

Collaborating, computing, researching, citing sources, analyzing, inferring, listening, communicating in writing and orally

ASSESSMENT

Students:

- Calculate their carbon footprints and take action to reduce their energy consumption and carbon output.
- Collaborate with others to conduct research into a form of alternative energy for Hawai'i and explain how it transfers and conserves energy compared to fossil fuels.

SUGGESTED TIMEFRAME

Two 45-50-minute class periods, plus group time to work independently on projects

Hawai'i State Standard Benchmarks

Science 2: Nature of Science - Science, Technology and Society

- **SC.6.2.2** Explain how the needs of society have influenced the development and use of technologies.

Science 6: Nature of Matter and Energy - Energy and its Transformation

- **SC.6.6.3** Explain how energy can change forms and is conserved.

Common Core Standards

Language Arts: Writing - Research to Build and Present Knowledge

- **W.6.8** Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources.
- **W.6.9** Draw evidence from literary or informational texts to support analysis, reflection, and research.

Language Arts: Speaking and Listening – Comprehension and Collaboration

- **SL.6.1** Engage effectively in a range of collaborative discussions with diverse partners on *grade 6 topics, texts, and issues*, building on others' ideas and expressing their own clearly.

Nā Honua Mauli Ola

'Ike Honua - Sense of Place Pathway

- **NHMO.8.14** Participate in conservation and recycling practices and activities.
- **NHMO.8.19** Identify and utilize appropriate forms of technology for improving the quality of life in their community.

MATERIALS

Provided

- Learning Log 7: My Carbon Footprint
- Learning Log 8: Energized!
- Learning Log 9: Research Plan
- Learning Log 10: Alternative Energy Source Data
- Getting Started: References for Students

For You to Provide

- 2 mini wind turbines
- 3 0.5 volt mini solar panels
- 5 digital multimeters
- Computers with presentation software

GETTING READY

- ✓ See Resources at the end of this lesson for suggested site for obtaining the mini wind turbines. solar panels, and digital multimeters.
- ✓ Make a copy of the Learning Logs for each student.
- ✓ Preview the EPA's webpage: A Student's Guide to Global Climate Change. Prepare to project the video on the home page to begin this lesson: http://www.epa.gov/climatechange/kids/
- ✓ Have some student volunteers assemble the mini wind turbines before the lesson.
- ✓ Prepare to project the graphs on carbon emissions provided in the Teacher Background Information section and plan to project the Getting Started page with student references (or copy this page as a handout).
- ✓ Arrange for computers to be available for students as they work on their team projects.

VOCABULARY

Alternative energy: energy sources that provide alternatives to fossil fuels, such as solar, wind, or tidal power

Biomass energy: power generated from burning plant-based sources

Carbon footprint: a measure of the amount of carbon emissions by a person or population

Geothermal power: energy generated from heat stored in the Earth

Green: in this context, adoption of alternative energy or sustainable practices that reduce carbon footprints

Hydropower: generating power by using moving water to power machinery or produce electricity

Solar power: generating useable energy from the sun either for heating hot water or for generating electricity by producing heat to power an electricity generator, or by converting sunlight to electricity directly with solar cells

Sustainable: a quality of meeting the needs of the present generation without compromising the ability of future generations to meet their own needs

Tidal power: a form of hydropower that converts the energy from the movement of water created by tides to production of electricity or other forms of power

Wave power: energy derived from the movement of waves and converted to electrical power or for other uses

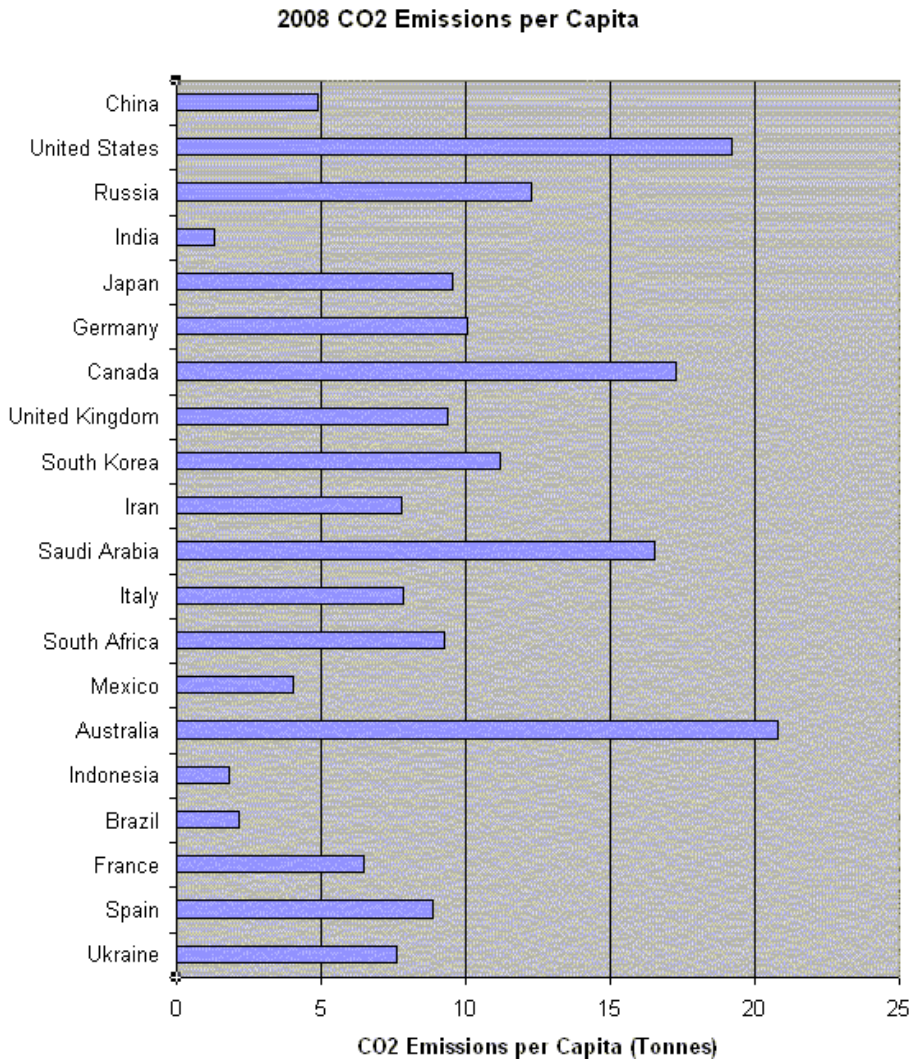
Wind power: energy transferred from the kinetic energy of wind

TEACHER BACKGROUND INFORMATION

"Addressing climate change is no simple task. To protect ourselves, our economy, and our land from the adverse effects of climate change, we must ultimately dramatically reduce emissions of carbon dioxide and other greenhouse gases.

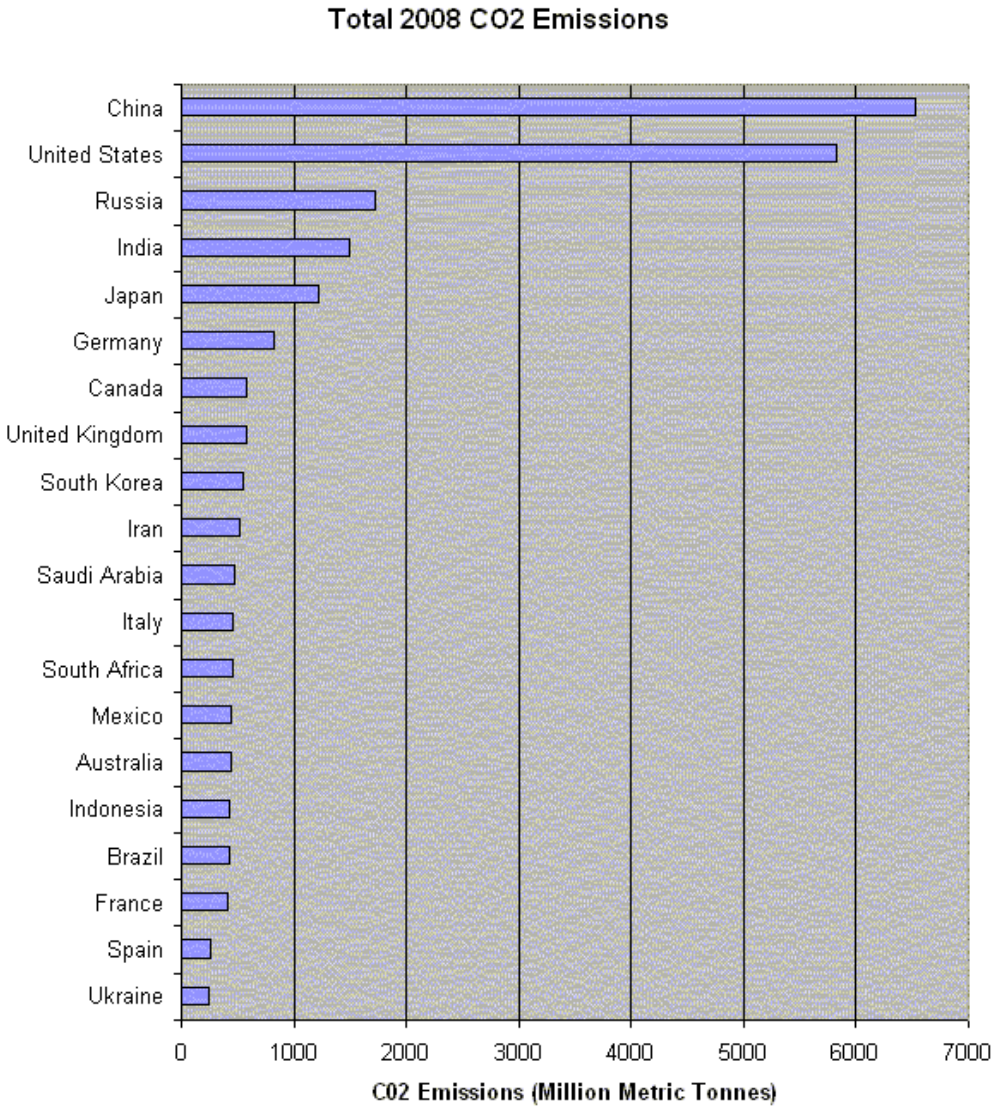
To achieve this goal we must fundamentally transform the way we power our global economy. This demands shifting away from a century's legacy of unrestrained fossil fuel use and its associated emissions in pursuit of more efficient and renewable sources of energy. Such a transformation will require society to engage in a concerted effort, over the near- and long-term, to seek out opportunities and design actions to reduce greenhouse gas emissions."

--Pew Center, Global Climate Change, Arlington, VA



Graph courtesy of Union of Concerned Scientists. Global Warming. 2010

Climate change is a global problem that will require global solutions. In December of 1997 the Kyoto Protocol was adopted in Kyoto, Japan. It is an international agreement that builds on the earlier 1992 United Nations Framework Convention on Climate Change in Rio de Janeiro, Brazil. The Kyoto Protocol set binding commitments to reduce greenhouse gas emissions, targeting an average 5% reduction from 1990 levels over a five-year period ending in 2012 (United Nations 2011). More than 160 countries have signed the Kyoto Protocol. The U.S. has not signed on, however individual states including Vermont and California and a number of U.S. cities are working to reduce CO_2 emissions to levels established in Kyoto. The graphs of the top 20 emitters of carbon dioxide and the per capita contributions highlight the need for the U.S. and for individuals in the U.S. to work toward reducing CO_2 emissions. Recent reports by the U.S Department of energy show that global CO_2 emissions jumped by the largest amount on record, rising 6% from 2009 to 2010 (Star Advertiser, 2011).



Graph courtesy of Union of Concerned Scientists. Global Warming. 2010

Oil, coal and natural gas provide 86.5% of the energy that powers countries around the globe and most of that (36.5%) is oil (Gore 2009). As students have seen, burning these nonrenewable sources of energy is the major contributor to carbon dioxide build-up in the atmosphere. To bring the carbon cycle back into balance and achieve sustainable lifestyles, we need to develop renewable, alternative sources of energy. These sources include solar, wind, geothermal, hydropower, and capturing the energy from tidal forces and waves.

In this lesson, student teams will each investigate a different form of alternative energy and prepare a presentation on the potential of this alternative "green" energy to reduce our carbon footprint in Hawai'i.

One source of alternative energy that may be new to students is ocean thermal energy conversion (OTEC). This technology uses the solar energy stored in upper layers of ocean water to vaporize ammonia and turn a turbine to generate electricity. The ammonia is cooled back to liquid form by deep cold ocean water, and the cycle of heating and vaporizing continues. For more information about this alternative energy source see the following website: http://www.oteci.com/

Students should explore whether the alternative energy source they are researching will be feasible for Hawai'i. For example, our tidal range is so small in the Islands that this form of energy may not be a good alternative. In addition, the cost of maintaining underwater ocean power stations is very high. Wave power may not be practical due to our steep underwater slopes, i.e. no continental shelf. However, wave power may still be under investigation as an alternative energy source for Hawai'i. In 2005 a small-scale wave energy buoy experiment (funded by the U.S. Navy) was initiated off Kāne'ohe Marine Corps Air Base. In 2008, plans were announced to build a 500 kw wave energy generator off Maui with a proposed operation date by end the of 2011. Results from these efforts have not yet been made public. For more information about this potential energy source, see: http://hawaiisenergyfuture.com/Articles/Wave_Energy.html

Teaching Suggestions

Introducing the lesson

1. **Recap what students have learned about climate change.**
   - Revisit the K-W-L chart that the class has been using to chart their passage through the unit.
   - Show the brief climate change video on the EPA's students' page: http://www.epa.gov/climatechange/kids/.
   - Introduce the focus question for this lesson.

   Focus Question: *How do we change the way we harness and use energy in Hawai'i to reduce our carbon footprint?*

- If students are unfamiliar with the concept of a "carbon footprint," define it.
- Review what students have learned about the carbon cycle and how the burning of fossil fuels has upset the balance of this cycle.
- Record students' initial responses to the focus question and discuss why we would want to reduce our carbon footprints.

NGSS:

Have pairs of students study the CO_2 emissions per country and per capita graphs and use this data to construct an argument about human population growth, use of fossil fuels, and impact on Earth's atmosphere and oceans.

2. **Project the graph showing the carbon dioxide emissions in tons per capita for different countries on the planet.** (See Teacher Background.)
   - Ask students to point out the countries that have the largest emissions.
   - Have students compare the total CO_2 emissions per country and per capita. Discuss why the U.S. emission of carbon per capita is so much greater than the world average.

Part 1: Going "Green"

3. **Distribute Learning Log 7 as homework.**
   - Ask students to work with their families to calculate their own carbon footprints.
   - When they have their results, discuss how their carbon emissions compare to the per capita emissions from other countries.
   - Distribute **Learning Log 8** and ask students to work in teams to complete the School section. Discuss their ideas.
   - Have students take Learning Log 8 home to discuss with their families and complete the checklist of things they can do at home to reduce carbon emissions.

If students don't have computers at home, have them ask their families the questions listed under no. 1 on Learning log 8 and calculate their carbon footprints online at school.

4. **Introduce alternative or "green" energy sources.**
   - Explain that Hawai'i now gets 90% of its energy from fossil fuels that are shipped into the state, but this will change if we meet the Hawai'i Clean Air Initiative's goal of using 70% renewable energy in the state by 2030.
   - Ask students to brainstorm a list of alternative ways that Hawai'i could generate energy.
     - Solar power
     - Wind power
     - Geothermal power
     - Wave power

- Tidal power
- Hydropower
- Biomass
- Ocean thermal energy conversion (OTEC)

- Ask students to describe what they know about these alternative energy sources and generate a list of questions they have about them. Add these to the K-W-L chart that was initiated in Lesson 1.

5. Divide the class into teams and distribute a mini solar panel or wind turbine to each team.

- Challenge teams to figure out the best way to generate the most energy with their resources.*
- Show them how to use the digital multimeters to measure the amount of energy generated. Set the dials on the multimeters at 20.
- Take the class outside and give teams about 15 minutes to try different locations and ways to generate energy.
- Call time and bring the groups together to share the amount of voltage that they were able to generate with the solar panels or wind turbines.
- Discuss their findings.
  - What did the teams that generated the most energy do to achieve success? Did any teams combine their panels or turbines?
  - Did it matter where the panel or turbine was set up? How?
  - How does the energy change forms with these alternative energy sources?
  - How is generating energy from wind and solar different from generating energy from fossil fuels?
  - How do wind and solar compare to fossil fuels in relation to impact on the carbon cycle?

** This part of the lesson is adapted from the curriculum, Island Energy Inquiry. See Resources listed at the end of the lesson.*

Part 2: Researching Alternatives

6. Divide the class into research teams and distribute Learning Logs 9 and 10 to get them started on research plans.

- Explain that each team is to conduct research into one form of alternative energy. Work with the class to make sure that different forms of alternative energy are being researched.
- Review **Learning Log 9** and ask teams to write their research questions and share these with the class.
- Review the other questions that teams should answer through their research.

- Project the **Getting Started** page with the student references to help them get started with their research.
- Ask each student on the team to complete **Learning Log 10** with a diagram of their selected alternative energy form and answers to the questions.

When forming teams for projects, be sure that students are grouped for success so that students with different strengths can pool their various talents.

7. **Model how to conduct research using both online resources and books.**
   - Show students how to search for information and how to paraphrase key points.
   - Write sample citations on the board for students to use in citing references.
   - Remind all students on a team to take notes and keep citations as they will need to turn in individual papers that answer the unit essential question by the end of the unit.
   - If you haven't already done so, post the date for the hō'ike where students will present their work to others. Note that the next lesson will help guide students to prepare for this event.

Extending the Learning

- Have the class go online to the Kanu Hawai'i website: http://www.kanuhawaii.org/ and make a commitment to take action to reduce their carbon footprints at school.

- Take students on a field trip to visit alternative energy sites on your island such as wind farms, solar facilities, geothermal or other sites. Check the Hawaiian Electric Co. website for information on clean energy projects around the state: http://www.heco.com

References

Gore, Al. *Our Choice: A Plan to Solve the Climate Crisis*. Emmaus, PA: Rodale, Inc. 2009.

Honolulu Star Advertiser. *Carbon Gas Emissions Leap to Record*. November 4, 2011.

Pew Center on Global Climate Change. "Global CO_2 Flows, Carbon Reservoirs, and Reservoir Changes" Accessed October 29, 2011 http://www.pewclimate.org/global-warming-basics/facts_and_figures/globalco2flows.cfm

Union of Concerned Scientists. Global Warming. 2010. Accessed October 31, 2011. http://www.ucsusa.org/global_warming/science_and_impacts/science/each-countrys-share-of-co2.html

United Nations Framework Convention on Climate Change. 2011. "Kyoto Protocol." Accessed October 31, 2011. http://unfccc.int/kyoto_protocol/items/2830.php

Resources

KidWind website: to order mini wind turbines ($34 each), 0.5 volt solar mini panels ($4 each), and digital multimeters to measure voltage ($12.50 each) http://www.kidwind.org/xcart/product.php?productid=414

Island Energy Inquiry: Science Curriculum for Hawai'i. 2010 This curriculum, produced by the Maui Economic Development Board, Inc. Women in Technology, is a comprehensive guide to alternative energy sources. There are many hands-on activities to engage learners in exploring sustainable energy use for Hawai'i. See: http://www.islandenergyinquiry.org/

LEARNING LOG 7:
MY CARBON FOOTPRINT

NAME_____ **DATE**_____

Find out how much carbon you and your family are emitting into the atmosphere.

1. Ask your family to help you answer these questions:

- Do we use Energy Star appliances? Energy-efficient light bulbs?
- How do we heat our water?
- What kind of car(s) do we drive?
- How often do we check the air filter and tire pressure on the car(s)?
- What happens to our food scraps? Yard clippings? Do we recycle?

2. Go to the Nature Conservancy's webpage: http://www.nature.org/initiatives/climatechange/calculator/ to calculate your carbon footprint.

3. Based on your carbon footprint results, answer the following questions:

- How many tons of carbon dioxide do you add to the atmosphere every year?
- Is this higher than the U.S. average? Is this higher than the world average?
- How do you feel about your carbon footprint?
- What could you and your family change about your lifestyle to reduce your carbon footprint? See **Learning Log 8** and discuss it with your family.

NAME_____ **DATE**_____

We know that our carbon emissions are contributing to the build-up of carbon dioxide in the atmosphere and that this is warming the Earth. So, what can we do to decrease our carbon footprints? Check the things that you will do to help the planet.

Home

- ☐ Unplug cell phones when finished charging.
- ☐ Turn off lights and unplug appliances when not in use.
- ☐ Turn down the setting on the water heater.
- ☐ Hang clothes on the line to dry.
- ☐ Buy locally grown food and other products.
- ☐ Switch to energy-saving light bulbs.
- ☐ Take shorter showers.
- ☐ Walk or ride a bike when possible, instead of riding in a car.
- ☐ Choose products that haven't been over-packaged.
- ☐ Recycle, reduce and reuse!
- ☐ Drink filtered tap water instead of bottled water.

School

Meet with students at your school and complete a checklist. Some of the items below are from students in other schools who are working on reducing carbon emissions.

- ☐ Ask parents to turn off car engines while waiting to pick up students - *If a car is idled 10 minutes less each day that saves 550 lbs (~248 kg) of CO_2 per year!*
- ☐ Ask the school bus to turn off idling engines while waiting. *Stopping one school bus from idling for a year could keep 400,000 lbs (180,000 kg) of CO_2 out of the atmosphere.*
- ☐ Start a recycling program.
- ☐
- ☐
- ☐
- ☐
- ☐

Learning Log 9: Research Plan

Team Member's Names_____

Our team is researching: (check one)

- ☐ Solar Power
- ☐ Wind Power
- ☐ Wave Power
- ☐ Tidal Power
- ☐ Geothermal Power
- ☐ Hydropower
- ☐ Biomass
- ☐
Other_____

Our main research question is:_____

_____

Other things to find out:

- How is energy captured in this form of alternative energy?
- How is energy converted for people to use?
- Is this a practical alternative for Hawai'i? Why or why not?

Sharing what we find out: Date of hō'ike (exhibit)_____

To answer the above questions, our team plans to create a... (select options)

- ☐ model to demonstrate how our alternative energy source works
- ☐ poster or poster board that explains how our alternative energy source works
- ☐ computer presentation with the facts and a drawing, photo, or diagram
- ☐ public service announcement that explains why we should use this source of energy
- ☐ brochure to share with our audience
- ☐ other_____

References: list of references we used in our research...

LEARNING LOG 10: ALTERNATE ENERGY SOURCE DATA

NAME_____ **DATE**_____

Focus Question: How is this energy "clean" technology? What problems does it solve?

Diagram of technology

Description of how energy is captured:

How is energy converted for people to use?

What problems or concerns might people have if they used this alternative source of energy? Why?

References to Begin Research

Websites:

U.S. Environmental Protection Agency. "A Student's Guide to Global Climate Change. Be a Part of the Solution."http://www.epa.gov/climatechange/kids/

Center for Climate and Energy Solutions. "Kids' Corner." http://www.pewclimate.org/global-warming-basics/kidspage.cfm

Hawai'i State Energy Office Energy Programs. "Energy Statistics." http://energy.hawaii.gov/resources/dashboard-statistics

Hawaiian Electric Company. "Hawaii's Energy Future: Moving Towards a Sustainable, Clean Energy Future." http://hawaiisenergyfuture.com/Articles/Wave_Energy.html

U.S. Department of Energy. Energy Efficiency and Renewable Energy. "Kids Saving Energy." http://www1.eere.energy.gov/kids/renergy.html

National Earth Science Teachers Association. "Tackling the Global Warming Challenge." *Windows to the Universe*. 2012. http://www.windows2universe.org/earth/climate/mitigation_intro.html http://www.windows2universe.org/earth/climate/mitigation_intro.html and energy: http://www.windows2universe.org/modules/energy/index.html

Books:

Cherry, Lynne and Gary Braasch. *How We Know What We know About Our Changing Climate. Scientists and Kids Explore Global Warming*. Nevada City, CA: Dawn Publications. 2008.

David, Laurie and Cambria Gordon. *The Down-to-Earth Guide to Global Warming*. New York: Orchard Books, an Imprint of Scholastic, Inc. 2007.

Kaye, Cathryn Berger. *A Kids' Guide to Climate Change and Global Warming: How to Take Action*. Minneapolis: Free Spirit Publishing. 2009.

Kai E‘e: Mounting Seas

Culminating Activity

How do we know if Hawai‘i’s sea level is rising due to global climate change and what can we do about it?

Activity at a Glance

Students collaborate in teams to answer the unit essential question. Each team reports on two topics: a clue to climate change, and a form of alternative energy. They produce a class computer presentation and individual teams select a method to report on an alternative energy source including models, posters, computer presentations, brochures or PSAs. Individually, students write papers to answer the unit essential question.

Key Concepts

- Developing and utilizing different alternative energy sources can help to reduce our carbon footprints and slow the process of climate change and sea level rise.
- Effective presentations include a logical sequence of ideas, relevant information, and thoughtful summaries and conclusions.
- Effective visual displays link to and help explain thinking and engage the audience in ideas.

Skills

Skills for this culminating activity are embedded in all of the activities in the unit.

Assessment

Students:

- Write a paper to answer the unit essential question using data collected and facts gathered in an organized manner, using a logical sequence of ideas and relevant, descriptive details.
- Collaborate in teams to research and report on:
  1) a clue to climate change and rising sea level
  2) a form of alternative energy for Hawai‘i; how it transfers and conserves energy and how it compares to fossil fuels.
- Add effective visual displays to their presentations to enhance the development of main ideas.

Hawai‘i State Standard Benchmarks

Science 2: Nature of Science - Science, Technology and Society

- **SC.6.2.1** Explain how technology has an impact on society and science.

Science 6: Nature of Matter and Energy - Energy and its Transformation

- **SC.6.6.3** Explain how energy can change forms and is conserved.

Hawai‘i General Learner Outcomes

- **GLO 3** - Complex Thinker
- **GLO 5** - Effective Communicator

Common Core Standards

Language Arts: Writing - Text Types and Purposes

- **W.6.2** Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

Language Arts: Speaking and Listening –Presentation of Knowledge and Ideas

- **SL.6.4** Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.
- **SL.6.5** Include multimedia components (e.g., graphics, images, music, sound) and visual displays in presentations to clarify information.

Nā Honua Mauli Ola

- **NHMO.8.14** Participate in conservation and recycling practices and activities
- **NHMO.7.1** Know what their kuleana is in various situations

Suggested Timeframe

Three 45-50-minute class periods plus hō'ike (exhibit)
Day 1: Work with students on design of culminating projects; review rubrics.
Day 2: Distribute Presentation Planners and practice presentations for hō'ike.
Day 3: Administer Unit Post-assessment and wrap up the unit.

Materials

Provided

- Student Assessment Overview (provided in Unit Introduction)
- Project rubrics and Pre/Post-assessment (provided in Unit Introduction)
- Self-Assessment Rubric
- Presentation Planner

For You to Provide

- Poster boards
- Marking pens
- Construction paper
- Digital camera
- Computers with presentation software

Getting Ready

- ✓ Review the culminating project rubrics provided in the Unit Introduction and prepare to project them and share them with students.
- ✓ Prepare to project the Self-Assessment Rubric provided with this lesson and make a copy of this and the Presentation Planner for each student.
- ✓ Ask students to bring their Learning Logs to class.
- ✓ Arrange for computers to be available for students as they work on their team projects.
- ✓ Copy the Unit Pre/Post-assessment for each student.

Teaching Suggestions

Part 1: Generating Unit Culminating Projects

1. Revisit the essential question for the unit and ask students to generate some initial responses to it.

Essential Question: *How do we know if Hawai'i's sea level is rising due to global climate change and what can we do about it?*

- Point out to students that their Learning Logs and their research on alternative energy will help them to now answer this two-part question.
- Review what they have learned about sea level rise and climate change.
- Discuss what they have learned to date about what we can do about climate change and sea level rise. Revisit the class K-W-L chart.

2. Review the culminating project descriptions in the Student Assessment Overview.

- Go over the group project description in the Overview (provided in the Unit Introduction). Discuss the challenge for each team to report on two topics in the hōʻike (exhibit) planned for the community:
  1) a clue to climate change and rising sea level, based on what they discovered in this unit
  2) a form of alternative energy for Hawaiʻi (initiated in Lesson 5)
- Ask teams to look at their graphic organizers on **Learning Log 6** that summarize clues to climate change. Have teams select the clues that they will report on, or assign these.
- Discuss ways that teams could present the climate change clues to an audience.
  - Each team could create two or three slides to present information and graphics related to their clues. These could be combined into a class presentation. Students could explore Prezi as a way to create a dynamic presentation. See Resources at end of lesson.
  - Use digital photographs from the field study and incorporate video or audio from interview segments.
  - Share highlights from correspondence with Alaskan or other Pacific students.
- Explain the 6 by 6 rule for developing good presentation slides--no more than 6 bullet points per slide, and no more than 6 words per bullet (to enable audience to read text on screen).
- Discuss team choices for presenting their alternative energy source (models, demonstrations, poster boards, videos, blogs, websites, brochures, public service announcements).

3. Review the culminating project rubrics with students.

- Review the details for students' individual papers and discuss ways that their contributions to the group project will help them to write their papers.
- Stress that each student needs to write his/her own paper.
- Project and review the rubrics for the group and individual projects and discuss criteria for doing high-quality work.

NGSS:

Challenge students to construct an argument in their papers, supported by evidence, for the benefits of using alternative energy in place of fossil fuels to reduce human impact on Earth's atmosphere and oceans by reducing CO_2 emissions.

Part 2: Presentation Planning

4. Monitor the alternative energy research projects initiated in the previous lesson.

- Have student teams meet and discuss what they are doing to laulima (work together) successfully on their projects.

- Project the self-assessment rubric provided in this lesson and review it with students. Hand out copies for each student and ask them to use pencils to rank themselves on where they think they are with each action at this point in their group work.
- Discuss strategies for working together successfully.

5. **Have students meet with their teams and work with the Presentation Planner.**
   - Distribute the Presentation Planners and review them with students.
   - Ask teams to divide up tasks and use a calendar to plot the time available to complete tasks before their hō‘ike.
   - Have students create a class invitation to the hō‘ike and distribute the invitations to other classes, school administrators, parents, kūpuna and others in the community.
   - If students will be presenting in classrooms, or an assembly, or community meetings, make sure that students consider how they will orchestrate these presentations and think carefully about their audience.

6. **Have students decide on the final plan for their presentations.**
   - Have teams report on the method they will use to share their information with the community.
   - If students need some motivation or help with presentation ideas, share the video that middle school students created as part of a climate change workshop with Hawai‘i Nature Center. (See Resources at end of lesson.)
   - Agree on a date when teams will practice presenting so that the class can pull together a cohesive presentation where everyone has a role to play.
   - Discuss effective presentation skills (sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; using appropriate eye contact, adequate volume, and clear pronunciation).

7. **When students have all completed their individual papers conduct a peer assessment.**
   - Have students work in pairs and exchange drafts of their papers with another student.
   - Ask students to conduct a peer-review of their classmate’s paper with constructive feedback for improving the paper.
   - Provide additional feedback on students’ papers and invite them to edit and resubmit. Ask them to submit their Learning Logs as well.

Part 3: Hō'ike and Unit Post-assessment

8. **Conduct final preparations and hold the hō'ike.**
   - Ask students to revisit their self-assessment rubrics and make any changes based on the work they completed with their teams.
   - Make sure arrangements have been made for any public performances or classroom visits.

9. **Administer the unit Pre/Post-assessment and wrap up the unit.**
   - Compare students' scores on the Pre- and Post-assessment and note any areas where further work may be needed to help students achieve standard benchmarks.
   - Distribute completed project rubrics and return Learning Logs and papers with feedback for students.
   - Encourage students to maintain their correspondence with students in the Pacific region.
   - Congratulate students on their work in completing the unit.

Resource

- http://www.youtube.com/watch?v=HgmYj7iY0n4 Middle school students in Hawai'i Nature Center's Climate Change program conduct interviews and share their views about climate change.

- If your students want to develop their own blogs or websites for their final projects, the following resources are available for easy implementation: http://www.simplesite.com (for developing blogs). http://www.top10bestwebsitebuilders.com (free templates with instructions for creating websites).

- The Prezi presentation tool is an option for creating dynamic presentations that allow students to group ideas and zoom in and out of text to make key points. See: www.prezi.com

Self-Assessment Rubric

Name: _____ Date: _____

Place a check in the box that matches your performance as a group member. Add up your points and answer the questions below.

	Maikaʻi loa! Excellent 4 points	**Maikaʻi Good 3 points**	**ʻAno Maikaʻi Okay 2 points**	**Auē! Not so good 1 point**
I did my best work for the team. It was in-depth, organized, neat and creative!				
I helped others when they needed my *kōkua*.				
I finished my work on time.				
I listened to others' ideas without being critical.				
I gave positive feedback to my team members.				
I asked for and used feedback from others.				
I think we did an awesome job as a team.				

Total Score _____

Explain what your contribution was to the team.

What was difficult for you in working with your team? Why?

How could you improve and help your team to be more effective? (If you need more room, use the other side of this sheet.)

TEAM #_____ PRESENTATION PLANNER

TEAM MEMBER'S NAMES_____

Essential Question: How do we know if Hawai'i's sea level is rising due to global climate change and what can we do about it?

	Our Climate Change Clue(s):_____ Our Alternative Energy Source:_____		
	Task: Climate Change Clue	**Who?**	**When?**
	Use information from Student Readings and Learning Logs to complete the graphic organizer on Learning Log 6. Organize information about your climate change clue.		
	Develop 2 or 3 PowerPoint slides about your climate change clue. Find graphics or photos and facts to support how your clue relates to climate change.		
	Cite your sources. Take notes in your own words of important information. Include quotations you may want to use. • Websites: locate relevant sites and save or print information • Books: take notes • Interview(s): identify segments you want to use		
	Assemble the PowerPoint Presentation. Work with other teams to combine slides into one class presentation on climate change.		
	Practice the presentation.		
	Team members each complete the Self-Assessment Rubric. How are you doing as a team?		

	Task: Alternative Energy Source	**Who?**	**When?**
	Complete research into alternative energy source. Take notes in your own words of important information. Include quotations you may want to use. • Websites: locate relevant sites and save or print information • Books: take notes • Cite your sources		
	Create model, display board, poster, brochure or other ways to teach others about your alternative energy source.		
	Submit any material such as brochures or handouts that need to be copied for the audience.		
	Practice the presentation (total length about 5 minutes). Divide up roles and responsibilities. Practice individually. Practice as a team, using your display board, model or other chosen method to share information. Present!		
List each team member's *kuleana* (responsibility).			

Team Member's Signatures:

_____

_____ Date:_____

Teacher's Initials_____

Kai E‘e – Mounting Seas

Pacific Tsunami and Climate Change Curriculum

Grade 8 - Climate Change Unit

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Introduction

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In Hawai‘i, we value our marine environment and shorelines as vital resources for us economically, socially, and environmentally. Sandy shores are main attractions for tourists, rocky coasts give fishermen an edge on their catch, coral reefs provide sustenance and protect shorelines, and breaking surf areas are recreational hotspots for surfers. But what would happen to these resources if sea level rose?

Scientists predict that within the next 100 years, sea level will rise by 3.3 ft (1 m) (Fletcher 2010). Imagine the Ala Wai Boat Harbor, Hilton Hawaiian Village lagoon, banks of the Ala Wai Canal, and most of the Ala Wai Golf Course submerged under water. Magic Island would become an actual island! (Leone 2007)

Sea level is slowly rising due to changes in our climate. Since 1950, the level of the greenhouse gas, carbon dioxide, has risen steadily. In fact, it is at the highest it has ever been in the last 650,000 years (NOAA 2007). Most recent data (March, 2013) record carbon dioxide levels in the atmosphere at 397 ppm. See: http://www.esrl.noaa.gov/gmd/ccgg/trends/ for updates on CO_2 in the atmosphere. With the increase of carbon dioxide and other greenhouse gases, Earth's climate is warming. Our warming climate is causing sea level to rise. The main causes of sea level rise are thermal expansion of ocean water and melting glaciers and ice sheets.

Island communities such as Hawai‘i are the most vulnerable to the effects of rising sea level. In this unit, students will explore different aspects of climate change and sea level rise and relate it back to their local island communities. The essential question for the unit is: *How do clues from our past and tools of the present help us prepare for future sea level rise?*

Assessment

The Unit Map that follows in this Introduction lays out the Hawai‘i DOE standards, the Common Core standards, and the Nā Honua Mauli Ola (Hawaiian Guidelines) on which the lessons are designed.

A Unit Pre / Post-assessment is provided on page 3. This one-page assessment consists of constructed response items aligned to standard benchmarks and key concepts from the lessons. The assessment is designed to administer at the beginning and at the end of the unit. The standard benchmarks and corresponding lessons for each item on the assessment are indicated on the answer sheet provided on pages 4 - 5.

In addition, the Next Generation Science Standards (NGSS) that correlate with the Hawai‘i Content and Performance Standards have been added to the Unit Map, lessons, and rubrics to assist teachers and students in making the transition to these new standards.

A unit summative assessment, which includes an individual and group project, is described in the Learning Log and in Lesson 5, the culminating activity. The rubrics provided with the unit are designed to assess students' culminating projects.

The first four lessons in the unit provide sequential steps to enable the students to successfully complete the culminating projects. The Learning Log pages provided with each lesson serve as a formative assessment. They are designed to be combined into a journal that documents students' learning as they progress through the unit.

The wave graphic that appears on each page is at the top of teacher pages, and at the

bottom of student pages so that these pages may be easily identified.

Unit Overview

In Lesson 1, The Rise of a Changing World, students are first introduced to the idea of sea level rise by watching a thermal expansion demonstration. Students then explore interactive global data using the Internet. A student reading and accompanying learning logs allow students to research data related to climate change.

In **Lesson 2, Water Power**, students work in groups to learn about and draw a topographic map of their school's area. From this map, they create a 3-dimensional model of the area's topography and discover the potential impact of sea level rise in their area.

In **Lesson 3, Learning from Nature's Clues**, students conduct interviews with family members and people from the community. Their goal is to document changes that have been observed by residents, to draw conclusions from the information, and then link this to climate change and sea level rise.

In **Lesson 4, Satellite "Eyes" on the Earth**, students will be captivated as they explore interactive websites about the many satellites that circle Earth and collect information about our climate. Students will use the websites to research information and work with real-time data. They will also look at the local birds-eye-view of sea level rise in Hawai'i.

The unit culminates with **Lesson 5, Taking Community Action**. In this lesson, students work in groups to discuss causes of sea level rise in their communities and determine ways to address these problems. Individually, they illustrate and write a short narrative about what sea level rise means to them. As a group, they work together to create a community action plan. They finally sum everything up in their hō'ike, where each group presents its community action plan to fellow students and the community.

Appendices

The Appendices provided with this unit include in-depth tips for videotaping interviews and two articles that supplement the background information provided in each lesson. The articles include the Environmental Protection Agency's summary of climate change indicators in the United States, a report by the U.S. Fish and Wildlife Service on climate change in the Pacific region, and a briefing sheet on Hawai'i's changing climate provided by Dr. Charles Fletcher of the University of Hawai'i, and Climate Change and Pacific Islands: Indicators and Impacts: Executive Summary.

The materials provided in this unit are designed with the intent of raising student awareness about a topic of vital importance to people living on islands--climate change and rising sea level. Exploring the complex interactions that lead to climate change and sea level rise as well as the actions we can take today, provide opportunities for both rigor and relevance in the curriculum that we provide for our students.

References

Fletcher, Charles H. *Hawai'i's Changing Climate Briefing Sheet, 2010*. Honolulu: University of Hawai'i Sea Grant College Program. Center for Island Climate Adaptation and Policy (ICAP). 2010.

Leone, Diane. "The drowning of Hawaii." Honolulu Star Bulletin, September 23, 2007. Accessed October 4, 2011. http://archives.starbulletin.com/2007/09/23/news/story01.html.

NOAA, 2007. "Climate Change." Accessed October 4, 2011. http://www.nws.noaa.gov/om/brochures/climate/Climatechange.pdf

KAI E'E GR. 8 UNIT PRE /POST-ASSESSMENT

NAME_____ **DATE**_____
SCHOOL_____

1. Circle two clues from the Earth's environment that indicate that climate change is occurring. Then make a check next to the factor that is a major cause of climate change.

Polar ice is expanding.	Carbon dioxide in the atmosphere is increasing.
Sea level is rising.	Deforested areas are still producing lots of oxygen.
Global surface temperatures are increasing.	Land mass is rising.

2. Over thousands of years there are changes that occur in the tilt and wobble of the Earth on its axis and in the shape of Earth's orbit. Describe how you think these changes could affect the Earth's climate.

3. Some 8th grade students made 3-dimensional models of the coastline near their school. They used a topographic map to help them create the model. How could they use this model to figure out if the estimated rise in sea level might affect landmarks in their community?

4. Some 8th grade science students noticed that many of the coral heads at the local reef had turned white, a process known as coral bleaching. The students are studying climate change. What data could they search for to see if there was a link between coral bleaching and climate change?

5. How might changes in the ocean environment lead to coral bleaching?

6. Scientists use satellite technology to monitor Earth's vital signs. Chose one of the vital signs from the list below. Then a) describe whether you think it is increasing or decreasing, and b) how the change may be related to human activities.
   Arctic sea ice Carbon dioxide Sea level Ozone hole

7. Identify the two direct causes for the predicted sea level rise of one meter by the turn of the century. Describe a sequence of events showing how the rising seas will affect our shorelines. Include descriptive details in your response. Write your answer on the back of this page.

Gr. 8 Unit Pre /Post-Assessment Answer Sheet

Question	Standard / Lesson	Answers	Total Possible Points
1. Circle two clues from the Earth's environment that indicate that climate change is occurring. Then make a check next to the factor that is a major cause of climate change. • Polar ice is expanding. • Sea level is rising. • Carbon dioxide in the atmosphere is increasing. • Deforested areas are still producing lots of oxygen. • Global surface temperatures are increasing. • Land mass is rising.	**SC.8.8.4** Explain how the sun is the major source of energy influencing climate and weather on Earth. Lesson: 1	Circle: • Sea level is rising. • Global surface temperatures are increasing. Check • Carbon dioxide in the atmosphere is increasing. *1 point for each correct response*	3 points
2. Over thousands of years there are changes that occur in the tilt and wobble of the Earth on its axis and in the shape of Earth's orbit. Describe how you think these changes could affect the Earth's climate.	**SC.8.8.3** Describe how the Earth's motions and tilt on its axis affect the seasons and weather patterns. Lesson 1	• These changes affect the amount and distribution of sunlight striking the planet causing it to vary over time. *(2 points)* These variations lead to changes in climate as the planet cools and warms. *(2 points)*	4 points
3. Some 8th grade students made 3-dimensional models of the coastline near their school. They used a topographic map to help them create the model. How could they use this model to figure out if the estimated rise in sea level might affect landmarks in their community?	**SC.8.1.1** Determine the link(s) between evidence and the conclusion(s) of an investigation. Lesson 2	• They could use the topographic map to mark elevations above sea level and mark where landmarks are located *(1 point)* and then add water to the model up to the elevation of projected sea level rise *(1 point)* and see which landmarks within that area would be flooded by rising sea level *(1 point)*.	3 points

4. Some 8th grade science students noticed that many of the coral heads at the local reef had turned white, a process known as coral bleaching. The students are studying climate change. What data could they search for to see if there was a link between coral bleaching and climate change? 5. How might changes in the ocean environment lead to coral bleaching?	**SC.8.5.1** Describe how changes in the physical environment affect the survival of organisms. **SC.8.1.1** Determine the link(s) between evidence and the conclusion(s) of an investigation. Lesson 3	• They could search for data on when coral bleaching events have occurred and data for average air and water temperatures over the years to see if bleaching events occur in the years that have warmer temperatures. *(2 points)* • The warming of the ocean water causes corals to lose the algae that live with them. When the algae are gone, the color of the coral is lost, which makes them appear bleached. *(2 points)* *2 points for each correct response*	4 points
6. Scientists use satellite technology to monitor Earth's vital signs. Chose one of the vital signs from the list below. Then a) describe whether you think each is increasing or decreasing, and b) how the change is related to human activities. • Arctic sea ice • Carbon dioxide • Sea level • Ozone hole	**SC.8.2.1** Describe significant relationships among society, science, and technology and how one impacts the other. Lesson 4	• Arctic sea ice (decreasing) • Carbon dioxide (increasing) • Sea level (increasing) • Ozone hole (increasing) *(1 point)* Changes in all vital signs are believed to be caused by human activities such as burning fossil fuels and cutting forests which increases greenhouse gases and leads to warming and climate change. *(1 point)*	2 points
7. Identify the two direct causes for the predicted sea level rise of one meter by the turn of the century. Describe a sequence of events showing how the rising seas could affect our shorelines. Include descriptive details in your response. Write your answer on the back of this page.	**W.8.3** Write narratives to develop real or imagined experiences or events using effective technique, relevant descriptive details, and well-structured event sequences. Lesson 5	Cause of sea level rise: • Water expands as it warms due to rising temperatures • Water rises as glaciers and ice sheets melt *(2 points)* Effects: Waves from higher seas will cause more beach erosion. Beach erosion causes loss of trees and other coastal plants, which affects animals. Rising sea level will cause flooding of roads and lead to damage to structures and landmarks. *(2 points)*	4 points

Essential Question: How do clues from our past and tools of the present help us predict future sea level rise?

Enduring Understandings:

- New technology tools enable us to predict tsunamis and gradual sea level rise over time.
- Geological evidence from the past, current data, and interviews with kūpuna and others provide clues to sea level changes in Hawai‘i.
- Sea level rise impacts shorelines, beaches, marine life, structures, and our quality of life on islands.
- Given the predictions for future sea level rise, we can take action today to plan for the future and protect our shorelines and beaches.

Nā Honua Mauli Ola (NHMO) Cultural Pathways:

‘Ike Honua - Sense of Place: Understand the symbiotic relationship between humans and their environment.

‘Ike Piko‘u - Personal Connection Pathway: Actively participate in communicating their concerns and ideas about their kuleana to the past, present, and future.

Values: kuleana (responsibility) and laulima (working together)

Unit Pre-Assessment:

Students complete a one-page assessment with constructed response items aligned to standard benchmarks and key concepts addressed in the unit. (Assessment provided in the Unit Introduction)

Culminating Project:

Students use two formats to answer the unit essential question - individually in writing, and then collaboratively.

Individually, students:

- Write a paper to summarize links between climate change evidence and future sea level rise predictions, to describe how sea level rise will affect their lives, and to envision how the community should adapt to sea level rise in the future.

In groups, students:

- Collaborate to develop a community action plan to address problems related to sea level rise.
- Report on their findings using posters, computer presentations, or other media.

Total 45-50-Minute Class Periods for Unit: 22 plus hō‘ike

Core Content Areas: Science, Language Arts and Math

Notes on Next Generation Science Standards (NGSS)

This unit map includes Next Generation Science Standards that correlate with the Hawai‘i Content and Performance Standards (HCPS) in Science. To increase the rigor of the unit and begin making the transition to NGSS, consider adjusting the assessments as suggested on the unit map for each lesson.

Suggestions for adapting the lessons for NGSS are also included in the margins next to the Teaching Suggestions within the lessons.

Rubrics for the culminating project have been designed for both HCPS and NGSS benchmarks to assist teachers and students in making the transition to NGSS.

1: The Rise of a Changing World

How is climate change related to global sea level rise?

Standards	Benchmarks	Next Generation Science Standards (NGSS)	Key Concepts
Science 2: Nature of Science - Science, Technology and Society **Science 8: Earth and Space Science** - Earth in the Solar System **Language Arts: Reading for Literature (RL)** - Craft and Structure **Math**: Functions	• **SC.8.2.2** Describe how scale and mathematical models can be used to support and explain scientific data. • **SC.8.8.3** Describe how the Earth's motions and tilt on its axis affect the seasons and weather patterns • **SC.8.8.4** Explain how the sun is the major source of energy influencing climate and weather on Earth. • **RL.8.4** Determine the meaning of words and phrases as they are used in a text, including figurative and connotative meanings; analyze the impact of specific word choice on meaning and tone, including analogies or allusions to other texts. • **8.F.5** Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). Sketch a graph that exhibits the qualitative features of a function that has been described verbally.	**Weather and Climate** **MS-ESS2-6** Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates. **MS-ESS3-5** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. **Structure and Properties of Matter** **MS-PS1-4** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when energy is added or removed.	• Thermal expansion and sea level change • Irregular pattern of Earth's orbit around the Sun and amount and distribution of sunlight striking the planet • Natural and accelerated climate change

Assessments	Assessment Adjustments for NGSS	Class Periods: 5
Students: • Analyze graphs to describe the functional relationship between carbon dioxide, global surface temperature and sea level. • Write a reflection about how global climate change affects sea level.	Students: • Develop and use a model (diagram, map, globe or digital model) to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates. • Design their own water thermometers to simulate how adding heat to water causes the water particles to move faster and the water to expand. Infer how this relates to global sea level rise.. • Ask questions to clarify evidence in their reflections about global climate change and sea level rise.	Student Pages • Student Reading 1 • Learning Logs 1 and 2 • Water Expansion Activity Instructions

2: Water Power

How is climate change related to local sea level rise?

Standards	Benchmarks	Next Generation Science Standards (NGSS)	Key Concepts
Science 1: The Scientific Process - Scientific Inquiry **Science 2: Nature of Science** - Science, Technology and Society **Science 5: Life and Environmental Sciences -** Diversity, Genetics, and Evolution **Math**: Expressions and Equations (EE) **Language Arts: Reading for Literature (RL)** - Craft and Structure	• **SC.8.1.1** Determine the links between evidence and the conclusions of an investigation. • **SC.8.1.2** Communicate the significant components of the experimental design and results of a scientific investigation. • **SC.8.2.1** Describe significant relationships among society, science, and technology and how one impacts the other. • **SC.8.5.1** Describe how changes in the physical environment affect the survival of organisms. • **EE.8.5** Graph proportional relationships, interpreting the unit rate as the slope of the graph. Compare two different proportional relationships represented in different ways. • **RL.8.4** Determine the meaning of words and phrases as they are used in a text, including figurative and connotative meanings; analyze the impact of specific word choice on meaning and tone, including analogies or allusions to other texts.	**Human Impacts** **MS-ESS3-2** Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.	• Topographic maps • Creating 3-D models from topographic maps • Using models to demonstrate different scenarios of sea level change, such as global sea level rise and tsunamis, and the impacts on landmarks • Problems related to sea level rise and affects on society, the economy, environment, and cultural sites

Assessments

Students:

- Complete a topographic map of the school's area and illustrate specific elevations and landmarks.
- Create a three-dimensional model using information from a topographic map.
- Analyze different scenarios for sea level rise using a three-dimensional model.
- Write a reaction paper about the impacts of sea level rise on their community.

Assessment Adjustments for NGSS

Students:

- Determine how forecasts for sea level rise should inform the development of technologies to mitigate the effect on their community.

Class Periods: 5

Student Pages

- Learning Logs 3 and 4
- Instructions for 3-D Models

3: Learning from Nature's Clues

What environmental clues provide evidence for climate change in Hawai'i?

Standards	Benchmarks	Next Generation Science Standards (NGSS)	Key Concepts
Science 1: Scientific Investigation **Science 5 Life and Environmental Sciences -** Diversity, Genetics, and Evolution **Language Arts: Speaking and Listening** - Comprehension and Collaboration **'Ike Pilina - Relationship Pathway**	• **SC.8.1.1** Determine the links between evidence and the conclusions of an investigation. • **SC.8.5.1** Describe how changes in the physical environment affect the survival of organisms. • **SL.8.1** Engage effectively in a range of collaborative discussions (one-on-one, in groups and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly. • **NHMO.1.3** Interact with kūpuna in a loving and respectful way that demonstrates an appreciation of their role as culture bearers and educators in the community.	**Human Impacts** • **MS-ESS3-4** Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.	• Interviewing community members to gain insights into changes in climate and ocean conditions • Preparation and adherence to certain protocols for interviews • Changing patterns of marine organisms in response to climate change and sea level rise

Assessments

Students:

- Describe the links between evidence and conclusions regarding environmental changes over time and climate change.
- Describe the effects of ocean and shoreline changes on the survival of marine life.
- Conduct interviews with family members, kūpuna, fishers or other community members familiar with the ocean and document their observations.

Notes

Assessment Adjustments for NGSS

Students:

- Write a summary of their findings, as an argument supported by evidence, of how increased human fossil fuel use is impacting climate and ocean conditions in Hawai'i.

Class Periods: 5

Student Pages

- "Hawai'i's Changing Climate Briefing Sheet" (in Appendix)
- Student Reading 2
- Learning Logs 5 and 6
- Group Charts

4: Satellite "Eyes" on the Earth

How can modern technology help us to measure and predict sea level changes and impacts?

Standards	Benchmarks	Next Generation Science Standards (NGSS)	Key Concepts
Science 1: The Scientific Process - Scientific Inquiry **Science 2**: **Nature of Science** - Science Technology and Society **Math**: Functions **'Ike Honua: Sense of Place Pathway**	• **SC.8.1.1** Determine the link(s) between evidence and the conclusion(s) of an investigation. • **SC.8.2.1** Describe significant relationships among society, science and technology and how one impacts the other • **SC.8.2.2** Describe how scale and mathematical models can be used to support and explain scientific data • **F.8.4** Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (x,y) values, including reading these from a table or from a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models, and in terms of its graph or a table of values. • **NHMO.8.9** Understand the symbiotic relationship between people and their environment.	**Weather and Climate** **MS-ESS3-5** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. **Human Impacts** **MS-ESS3-2** Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.	• Growth of technology over time - new tools to predict sea level changes • Examining data and looking at patterns of association between quantities

Assessments	Assessment Adjustments for NGSS	Class Periods: 3
Students: • Develop graphs and interpret information using real-time data. • Describe the meaning of symbols on charts and their connection to sea level change. • Interpret sea level predictions and connect these predictions to the use of technology. • Draw conclusions about data derived from satellite information.	Students: • Ask questions about the data collected by satellites to clarify evidence of the factors that have caused the rise in global temperatures over the past century. • Analyze and interpret satellite data to forecast future sea surface temperature and sea level rise based on current trends. Discuss technology to mitigate the effects.	Student Pages • Learning Logs 7, 8, and 9

5: Taking Community Action

How do clues from our past and tools of the present help us prepare for future sea level rise?

Standards	Benchmarks	Next Generation Science Standards (NGSS)	Key Concepts
Science 1: The Scientific Process - Scientific Inquiry **Science 2: Nature of Science** - Science, Technology, and Society **Language Arts: Writing** - Production and Distribution; and Text Types and Purposes **Language Arts**: **Speaking and Listening** - Presentation of Knowledge and Ideas **ʻIke Honua - Sense of Place Pathway** **ʻIke Pikoʻu - Personal Connection Pathway**	• **SC.8.1.1** Determine the link(s) between evidence and the conclusion(s) of an investigation. • **SC.8.2.1** Describe significant relationships among society, science, and technology and how one impacts the other. • **W.8.6** Use technology including the Internet, to produce and publish writing and present the relationships between information and ideas efficiently as well as to interact and collaborate with others. • **W.8.3** Write narratives to develop real or imagined experiences or events using effective technique, relevant descriptive details, and well-structured event sequences. • **SL.8.4** Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. • **SL.8.5** Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. • **NHMO.8.9** Understand the symbiotic relationship between humans and the environment. • **NHMO.5.2** Actively participate in communicating their concerns and ideas about their kuleana to the past, present, and future.	**Interdependent Relationships in Ecosystems** **MS-LS2-5** Evaluate competing design solutions for maintaining biodiversity and ecosystem services. **Human Impacts** **MS-ESS3-3** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.	• New technology tools for predicting tsunamis and sea level rise • Geological evidence from the past, current data, and interviews with kūpuna related to sea level changes in Hawaiʻi • Sea level rise impacts on shorelines, beaches, marine life, structures, and quality of life • Taking action today to plan for the future and protect our shorelines and beaches
Assessments See first page of Unit Map.	Assessment Adjustments for NGSS Student Groups: • Develop a method for monitoring one of the climate change indicators in their community. • Compare and evaluate effectiveness of group member's solutions for adapting to and mitigating damage from sea level rise and design solutions based on best ideas of the group.		**Class Periods:** 4 plus hōʻike Student Pages • Self-assessment Rubric • Learning Logs 10 and 11 • Task Cards

NAME_____**DATE**_____ **POINTS**_____

Essential Question: How do clues from our past and tools of the present help us prepare for future sea level rise?

Standards	Below Points_____	Approaching Points_____	Meets Points_____	Exceeds Points_____
Language Arts - Writing **W.8.3** **GLO 3 - Complex Thinker**	• Narrative used few or no descriptive details • Did not explain causes and effects of problems or solutions related to sea level rise in our community	• Narrative used some descriptive details • Partially explained causes and effects of problems and a potential solution to one problem related to sea level rise in our community	• Narrative used relevant descriptive details and effective techniques • Explained causes and effects of problems and potential solutions related to sea level rise in our community	• In-depth development of effective technique, relevant descriptive details, and well-structured event sequences • Explained causes and effects of problems and potential solutions related to sea level rise in our community
Science **SC.8.2.1**	• Writing and illustration did not make connections between society, science, and technology and how one impacts the other	• Writing and illustrations made minimal connections between society, science, and technology and how one impacts the other	• Writing and illustrations made connections between society, science, and technology and how one impacts the other	• Writing and illustrations presented detailed connections between society, science, and technology and how one impacts the other
Science **SC.8.1.1**	• Narrative did not include links between evidence of climate change to predictions for rising sea level	• Narrative discussed evidence but needed to more clearly link evidence of climate change to predictions for rising sea level	• Narrative showed the links between climate change evidence and predictions for rising sea level	• Narrative showed the links between different forms of evidence for climate change and predictions for rising sea level

NAMES_____ **DATE**_____ **POINTS**_____

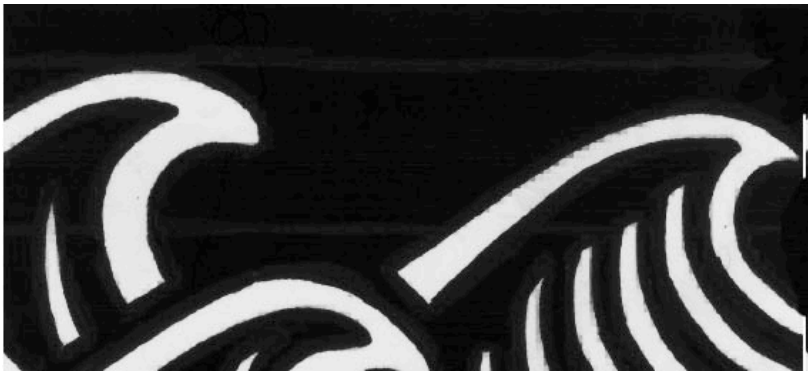
Essential Question: How do clues from our past and tools of the present help us prepare for future sea level rise?

Standards	Below Points_____	Approaching Points_____	Meets Points_____	Exceeds Points_____
Science 2: Nature of Science SC.8.2.1	• Did not clearly describe data collected in the unit • Recognized relationships among society, science, and technology but did not describe them	• Described some of the data collected in the unit • Listed a few relationships between society, science or technology	• Described data collected in the unit • Described relationships among society, science, and technology and how one impacts the other	• Provided an analysis of data collected in the unit • Described significant relationships among society, science, and technology and how one impacts the other
Language Arts - Writing W.8.6	• Did not use technology, including the Internet, effectively to present the relationships between the problem and solutions in your community action plan • Team members need to work on collaboration skills if you are going to produce better quality work.	• Used technology, including the Internet, somewhat effectively to present the relationships between the problem and solutions in your community action plan • Some team members need to work on collaboration skills to produce better quality work.	• Used technology, including the Internet, to clearly present the relationships between the problem and solutions in your community action plan • Team members interacted and collaborated to produce good quality work.	• Used technology, including the Internet, to creatively present the relationships between your problem and solutions in your community action plan • Team members worked together effectively to produce excellent quality work.

Language Arts - Speaking and Listening SL.8.4 **GLO 5 - Effective Communicator**	• Did not present the problem or did not present it clearly due to lack of focus, relevant evidence, or sound valid reasoning and details • Team members did not speak clearly or make eye contact to engage the audience.	• Presented the problem but needed to be more focused, use more relevant evidence, or use sound valid reasoning and details • Team members sometimes spoke clearly and made eye contact, but need to work on this in order to engage the audience.	• Presented the problem in a focused, manner using relevant evidence, sound valid reasoning, and/ or well-chosen details. • Team members spoke clearly and made eye contact to engage the audience.	• Presented the problem in a focused, coherent manner using relevant evidence, sound valid reasoning, or well-chosen details. • Team members were animated, spoke clearly, and made eye contact to engage the audience.
Language Arts - Speaking and Listening SL.8.5	• Did not integrate multimedia and visual displays into your presentation to clarify information, strengthen claims and evidence, or add interest	• Integrated multimedia and visual displays into your presentation, but it did not clarify information, strengthen claims and evidence, and/or add interest	• Made good use of multimedia and visual displays in your presentation to clarify information, support claims and evidence, and add interest	• Excellent integration of multimedia and visual displays into your presentation, which clearly clarified information, strengthened claims and evidence, and added interest
NGSS Life Science MS-LS2-5	• Did not compare or evaluate group member's solutions for adapting to and mitigating damage from sea level rise. • Did not design solutions using the best ideas of the group.	• Compared group member's solutions for adapting to and mitigating damage from sea level rise, but did not pull out the most effective ideas and incorporate them into the group solution.	• Compared and evaluated effectiveness of group member's solutions for adapting to and mitigating damage from sea level rise. • Designed solutions using the best ideas of the group.	• Compared and evaluated effectiveness of group member's solutions for adapting to and mitigating damage from sea level rise. • Designed innovative solutions building on the best ideas of the group.
NGSS Earth and Space Sciences MS-ESS3-3	• Did not develop a method for monitoring one of the climate change indicators in our community.	• Shared an incomplete idea for monitoring one of the climate change indicators in our community.	• Developed a method for monitoring one of the climate change indicators in our community.	• Developed effective methods for monitoring one or more of the climate change indicators in our community.

Learning Log

Kai E‘e – Climate Change



Name: _____

School: _____

Date Started: _____

Date Completed: _____

UNIT ASSESSMENT OVERVIEW

UNIT ESSENTIAL QUESTION: *How do clues from our past and tools of the present help us prepare for future sea level rise?*

NĀ HONUA MAULI OLA (NHMO) - HAWAIIAN CULTURAL PATHWAYS

'Ike Pilina - Relationship Pathway

- Interact with kūpuna in a loving and respectful way that demonstrates an appreciation of their role as culture bearers and educators in the community.

'Ike Piko'u - Persona Connection Pathway

- Actively participate in communicating their concerns and ideas about their kuleana to the past, present, and future.

'Ike Honua - Sense of Place Pathway

- Understand the symbiotic relationship between people and their environment.

Values: kuleana (responsibility) and laulima (working together)

LESSONS, STANDARDS, AND LEARNING LOGS	COMPLETED ✓
1. The Rise of a Changing World - Science 2 and 8; Language Arts - Reading 8, Math - Functions 5 Learning Logs 1 and 2	
2. Water Power - Science 1, 2, and 5; Math - Expressions and Equations 5, Language Arts - Reading 4 Learning Logs 3 and 4	
3. Learning from Nature's Clues - Science 1 and 5; Language Arts - Speaking and Listening 1 Learning Logs 5 and 6	
4. Satellite "Eyes" on the Earth - Science 1 and 2; Math - Functions 4 Learning Logs 7, 8 and 9	
5. Taking Community Action - Science 1 and 2; Language Arts: Writing 6 and 3, and Speaking and Listening 4 and 5 Learning Logs 10 and 11 Self-assessment Rubric	

GROUP PROJECT DUE DATE:_____

Work with a team to develop a community action plan that addresses a problem related to future predicted sea level rise.

Your team will need to use technology, including the Internet, to report on the following two topics:

1) A problem due to rising sea level, based on what we discover in this unit, and

2) An action plan that addresses how your group would solve this problem.

For each of these topics, your team will need to:

- Analyze the topic.
- Report on data collected in the unit and describe the relationships among society, science and technology.
- Collaborate with your team members and work with other teams to share data, draw conclusions and produce high-quality work.
- Develop a presentation to present your findings using a method of your team's choice: Powerpoint presentations, PREZI, demonstrations, models, poster boards, videos, or public service announcements to others in the community.

INDIVIDUAL PROJECT DUE DATE:_____

Create an illustration and a narrative at least two pages in length to answer the unit essential question. Share these documents with members of your group. Based on these illustrations and narratives, your group will create a unified presentation.

Your illustration and narrative should:

★ Address the following:
- How climate change and sea level rise will impact your life in our community.
- What you would like your future in Hawai'i to look like in respect to sea level rise.

★ Make connections between society, science and technology to answer the unit essential question: *How do clues from our past and tools of the present help us prepare for future sea level rise?*

★ Show the links between climate change evidence and predictions for future sea level rise in our community.

★ Use relevant descriptive details to explain the causes and effects of problems related to sea level rise in our community.

★ Include an introduction and conclusion. We will review rubrics to help guide you in developing your projects.

The Rise of a Changing World

How is climate change related to global sea level rise?

Activity at a Glance

Students conduct a demonstration to explore how thermal expansion can cause sea level rise. Through a Student Reading, Learning Logs and interactive graphs online, students investigate key climate change indicators and write a reflection about causes for sea level rise.

Key Concepts

- As water heats up, temperature increases causing water to expand and thus, water levels rise. When the ocean is heated by global warming, it expands causing sea level change.

- Due to the irregular pattern of Earth's orbit around the Sun, the amount and distribution of sunlight striking the planet varies over time. This variation leads to changes in sea level as the planet cools and warms.

Skills

Creating charts and graphs, interpreting data, observing, reading comprehension, critical thinking, developing vocabulary

Assessment

Students:

- Analyze graphs to describe the functional relationship between carbon dioxide, global surface temperature and sea level.

- Write a reflection about how global climate change affects sea level.

Time

Five 50-minute class periods

Day 1: Introduction and unit pre-assessment

Day 2: Shoreline observations and Learning Log 1

Day 3: Review Learning Log and water expansion activity

Days 4 - 5: Exploring climate change data and Learning Log 2

Hawai'i State Standard Benchmarks

Science 2: Nature of Science - Science, Technology and Society

- **SC.8.2.**2 Describe how scale and mathematical models can be used to support and explain scientific data.

Science 8: Earth and Space Science - Earth in the Solar System

- **SC.8.8.3** Describe how the Earth's motions and tilt on its axis affect the seasons and weather patterns.

- **SC.8.8.4** Explain how the sun is the major source of energy influencing climate and weather on Earth.

Common Core Standards

Language Arts: Reading

- **R.8.4** Determine the meaning of words and phrases as they are used in a text, including figurative and connotative meanings; analyze the impact of specific world choice on meaning and tone, including analogies or allusions to other texts.

Math: Functions - Use Functions to Model Relationships Between Quantities

- **8.F.5** Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). Sketch a graph that exhibits the qualitative features of a function that has been described verbally.

Materials

Provided

- Learning Log cover, Student Assessment Overview, and Unit Pre-assessment (provided in Unit Introduction)
- Student Reading 1: Part 1: Earth's Changing Climate; Part 2: The Greenhouse Effect
- Learning Log 1: Earth's Changing Climate
- Learning Log 2: Climate Indicators
- Water Expansion Activity Instruction Sheet

For You to Provide

Learning Log Materials

- Folders (one per student for Learning Logs)
- Glue

Water Thermometer Activity (One set per group of 3 to 4 students)

- Tall plastic water bottle
- Small piece of modeling clay or playdough
- Clear straw
- Food coloring (blue)
- Container filled with hot water
- Container filled with cold water

Getting Ready

✓ Review the Student Assessment Overview and the Unit Pre-assessment provided in the Unit Introduction and make a copy for each student.

✓ Make a copy of the Learning Logs and Student Reading for each student.

✓ Prepare the water expansion activity: Collect materials, make copies of the instructions for each group, and prepare containers of very hot and very cold water (see Water Expansion Activity Instruction Sheet).

✓ Preview and prepare to project the following website for students (or have them work in small groups on classroom computers): NASA's Global Climate Change Vital Signs of the Planet website (http://climate.nasa.gov/keyIndicators/). Have students check the website for updated data compared to what is provided on their Learning Logs.

Vocabulary

Albedo: the ratio of the light reflected by a planet or satellite to that absorbed by it

Climate change: significant changes in temperature, precipitation, wind and other weather patterns over an extended period of time; in this context, a change due to an increase in the average global atmospheric temperature

Eccentricity: the distance between the centers of the Earth and Sun

11-Year Solar Cycle: the periodic change in the amount of irradiation from the Sun that is experienced on Earth approximately every 11 years

Global warming: an increase in the Earth's average atmospheric temperature that causes corresponding changes in climate and that may result from the greenhouse effect

Milankovitch Cycles: changes in the Earth's movement with respect to the Sun that alters the amount and location of solar radiation reaching Earth

Obliquity: the angle of tilt of the Earth's rotational axis relative to the Earth's plane of orbit around the Sun

Precession: the conical motion of the Earth's axis of rotation

Sea level: a measure of the average height of the ocean surface, which is also used as a standard to define land elevation

Thermal expansion: in this context, the process of ocean water increasing in volume as the water temperature increases

TEACHER BACKGROUND INFORMATION

Climate change has occurred for hundreds of millions of years as a natural process. This natural cycle occurs because of interactions between the atmosphere, ocean, land, and changes in the amount of solar radiation that reaches the Earth. An example of natural climate change is the last Ice Age when Earth cooled to such an extreme extent that ice covered vast portions of the Earth. Beyond the natural causes for climate change are the human-induced changes that are warming the planet at an unprecedented rate. Within the last century, there has been an incredible increase in the amount of greenhouse gases within our atmosphere. Since the Industrial Revolution, the increased burning of fossil fuels, like oil, coal and natural gas has added carbon dioxide and other gases into the atmosphere. As the greenhouse gases (e.g., carbon dioxide, methane, nitrous oxide and water vapor) trap heat within our atmosphere, Earth warms up, much like the interior of a greenhouse in the sun. In fact, carbon dioxide levels are the highest they have ever been in the last 650,000 years which is adding to the increased temperatures (NOAA 2007). From data collected on top of Mauna Loa on Hawai'i Island, scientists have recorded increases in carbon dioxide in our atmosphere since 1958. The data indicate that the amount of CO_2 in the atmosphere has increased from 316 ppm (parts per million) to approximately 389 ppm in September 2011. Recent trends are even higher; in March 2013, the CO_2 level in the atmosphere reached 397 ppm. (See: http://www.esrl.noaa.gov/gmd/ccgg/trends/ for updates on CO_2 in the atmosphere.)

Climate change is difficult to predict, however scientists study the Earth's past to make sound predictions of what could happen in the future. Some of the key indicators of global climate change are the concentrations of carbon dioxide, global surface temperatures, the amount of Arctic sea ice, the amount of land ice and sea level. Together, these indicators paint a picture of what is happening on Earth and allow us to prepare for future changes and to change our behaviors to prevent negative outcomes (NASA, Jet Propulsion Laboratory 2011).

Sea Level Rise

Sea level rise is the focus of this unit. Changes in sea level are generally attributed to two factors: the melting of glacial land ice and the thermal expansion of sea water. Ice from the polar regions is breaking off and melting regularly. With Earth's increased temperatures, ice melt is accelerating adding more water to our oceans, thus causing sea level to rise. Increased carbon dioxide in the atmosphere, warming air temperatures, and increased ice melt are all factors in rising sea level.

Scientists have found a relationship between past global surface temperatures and past fluctuations in sea level. They have determined that sea level has been rising steadily since 1900 at a rate of approximately .04 to .098 in (1 to 2.5 mm) per year. With new satellite altimetry technology, even more accurate data can be gathered. According to data collected from the TOPEX/Poseidon satellite, sea level has been rising at a rate of .12 in (~3 mm) per year since 1992 (NOAA 2011).

On an international level, the Intergovernmental Panel on Climate Change (IPCC) estimated in its Fourth Assessment Report (2007) that, "there is strong evidence that global sea level

gradually rose in the 20th century and is currently rising at an increased rate, after a period of little change between AD 0 and AD 1900. Sea level is projected to rise at an even greater rate in this century." This report predicts that total global-average sea level rise from 1990 to 2100 can be as low as 7 to 15 in (17.8 to 38.1 cm) for low emission scenarios or as high as 10 to 23 in (25.4 to 48.4 cm) for high emission scenarios (NOAA 2011). Many scientists now view even the high-emissions scenario of the IPCC as being too conservative. In Hawai'i, scientist Dr. Charles Fletcher is projecting a 3.3 ft (1 m) rise in sea level by the end of this century (Fletcher 2009). More recent research takes into account the inundation of groundwater in low-lying areas of Honolulu as sea level rises. Since groundwater tables in low-lying areas are near the ground surface, the combined effect of flooding due to sea water inundation and flooding due to groundwater rising to the surface, doubles previous predictions of flooding (Rotzoll and Fletcher 2012).

For island communities such as Hawai'i, sea level rise is a very real and serious topic. Many of our coastal communities would need to be relocated. Our marine resources would be drastically altered. There will be incredible economic impacts. Our island way of life would not be the same. In this lesson, students explore sea level rise and its relationship with climate change on a global scale. As they progress through the unit, they will learn how this bigger picture affects our island way of life.

Teaching Suggestions

Introducing the Unit

1. UNIT PRE-ASSESSMENT: Post the essential question for the unit.

Essential Question: *How do clues from our past and tools of the present help us prepare for future sea level rise?*

- Distribute the unit pre-assessment and ask students to write their names, the name of the school and the date at the top of the page.
- Explain that some scientists are predicting a one meter rise in sea level in Hawai'i by the turn of the century. Explain that during the course of the unit, students will be piecing together clues to climate change and sea level rise and sharing what they learn with others. To get started, ask them to answer the questions on the **Pre-assessment** to the best of their ability. Explain that they will not be graded on the assessment, but it will help to show what they may already know about climate change and sea level rise.
- Collect student responses and save them for comparison with post-assessment at the end of the unit.

- Discuss what students knew about sea level and climate change and what they wonder about these topics.

2. Introduce the Student Assessment Overview (from the Unit Introduction) and review it.

- Distribute the materials for the Learning Logs.
- Have students glue the Learning Log cover to the folder and glue the assessment overview to the inside cover.
- Review the unit culminating projects and assign due dates.

NGSS:
Challenge groups of students to develop and use a model (diagram, map, globe or digital model) to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

Part 1: Earth's Changing Climate

3. Take students to the beach to observe the shoreline.

- Have students observe the shoreline and ocean in solitude for 10 minutes.
- Gather the students in a large group and ask them to share what they observed.
  - Are there clues that show sea level rise? What are they?
  - Is there a line along the shore showing where the highest tide is?

NGSS:
Have student groups design and test their own water thermometers.

4. At the beach, introduce students to the lesson's focus question and discuss it.

- Focus question: *How is climate change related to global sea level rise?*
- Ask students to share their initial ideas about this topic.
  - Is sea level rising? If so, how do we know and what would cause sea level to rise?

5. Have students read Student Reading 1: Part 1 aloud and discuss it in class. Ask them to complete Learning Log 1.

- To help them better understand Milankovitch Cycles, show the online video about this topic at: http://video.nationalgeographic.com/video/national-geographic-channel/shows/naked-science/ngc-ice-age-cycles/.
- Review students' responses to Learning Log 1.

6. Have students explore water expansion by creating their own water thermometer.

- Divide the class into groups of 3 to 4 students.
- Distribute the Water Expansion Activity Instruction Sheet to each group and review it. After conducting the activity, discuss with students what happened and why.

- As water temperature increases, what happens to the water level?
  - Why does the water level rise?
  - How does this relate to our Earth and sea level rise?

Part 2: Global Data

7. Present the global data and have students determine its correlation to sea level rise.

NGSS:

Have students ask questions in their reflections to clarify evidence about global climate change and sea level rise.

8. Using a projector or individual computers, go to NASA's Global Climate Change Vital Signs of the Planet website (http://climate.nasa.gov/keyIndicators/).

- Discuss vocabulary (i.e. average, mean, slope) to help students better understand graphs.
- Scroll over the Carbon Dioxide Concentration Time Series. Draw the students' attention to the meaning of different colors and their changes over time. Are there significant changes in colors? What does this indicate?
- Scroll over the Global Surface Temperature Time Series. Again, draw the students' attention to the meaning of different colors and their changes over time. Discuss these changes in color and reasons for these changes.
- Scroll over the Sea Level Time Series. Does it appear that sea level has changed since 1993?
- Discuss the correlation between these three Time Series.

9. Distribute Learning Log 2 and review it.

- Have students complete the Learning Log and provide access to the Internet as needed.
- Discuss students' answers. Do their answers to The Big Picture reflect their understanding of the overall correlations among CO_2, global surface temperature, and sea level?

Extending the Learning

- While using NASA's Time Series, have students complete a table for each Climate Change Indicator that lists each year and percentages of colors. Have students graph these percentages.

- Use the other Climate Change Key Indicators listed on NASA's website and compare that information with sea level rise.

- Have students make models of the Milankovitch Cycles and explain their models to the class.

References

Bergman, Jennifer. "How the Sun Affects Climate: Solar and Milankovitch Cycles." 2008. Accessed October 5, 2011. http://www.windows2universe.org/earth/climate/cli_sun.html.

Fletcher, Charles H. "Sea Level By the End of the 21st Century: A Review." *Shore and Beach*. Vol. 77, No. 4. Fall 2009.

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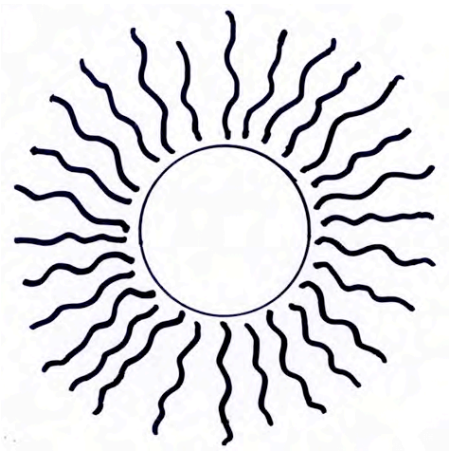
Rotzoll, Kolja and Charles H. Fletcher. "Assessment of Groundwater Inundation as a Consequence of Sea Level Rise." *Nature Climate Change*. DOI: 10.1038/NCLIMATE1725. Accessed June 6, 2013. http://www.soest.hawaii.edu/soest_web/2012_news_PDFs/Rotzoll_NatureClimate_FINAL.pdf

Sussman, Art. *Dr. Art's Guide to Science. Connecting Atoms, Galaxies, and Everything in Between*. San Francisco, CA: Jossey-Bass in partnership with WestEd. 2006.

Resources

A demonstration video by Steve Spangler illustrates how to create the water thermometer. See: http://www.stevespanglerscience.com/lab/experiments/water-thermometer-sick-science

The Virtual Courseware Project has interactive online simulations of the Milankovitch Cycles. See: http://www.sciencecourseware.org/eec/GlobalWarming/Tutorials/Milankovitch/.



Student Reading 1:
Part 1: Earth's Changing Climate

The Sun is the single most important source of energy for Earth. It warms the planet, the oceans and the atmosphere which then powers our weather and water cycles. The Sun's energy also allows plants to grow. These plants then produce the oxygen that we need to survive. Without the Sun, there would be no life on Earth.

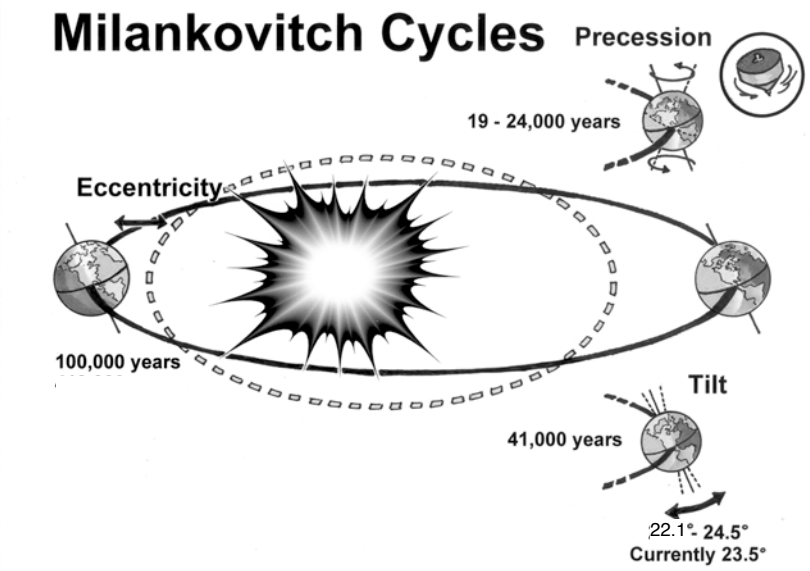
As the Sun's energy travels toward our planet, some of it is absorbed by the planet or trapped in the atmosphere, and approximately one-third of it is reflected back into space. The amount of energy that Earth receives varies because of changes in the Sun, the Earth's orbit and Earth's albedo (reflectivity). These natural variations result in changes in our climate.

The 11-Year Solar Cycle

The Sun has sunspots that radiate energy. When the Sun has many sunspots, lots of energy reaches our planet and our planet heats up. When the Sun has fewer sunspots, less energy is emitted and our climate cools down. This was the case during the "Little Ice Age" that occurred more than 300 years ago. During this time, people noticed that there were no sunspots for several decades. Over time, scientists noticed that about every 11 years, the number of sunspots on the Sun reaches a high and then decreases again. This has become known as the 11-Year Solar Cycle.

Milankovitch Cycles

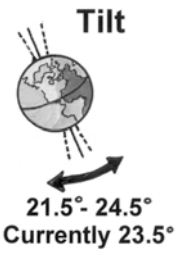
In the mid-1900s, astronomer Milutin Milankovitch hypothesized three cycles that occur over thousands of years where the tilt and wobble of the Earth on its axis and the shape of its orbit changes. These changes affect the amount and distribution of sunlight striking the planet causing it to vary over time. These variations lead to changes in climate as the planet cools and warms.



To help you understand these cycles see: http://video.nationalgeographic.com/video/national-geographic-channel/shows/naked-science/ngc-ice-age-cycles/

There are three ways that the Earth's orbit changes over time:

- **Eccentricity**: Every 100,000 years, the shape of the Earth's orbit around the Sun becomes more and then less oval. To better understand this, imagine that the Earth's orbit is like a big rubber band. Sometimes it's stretched tight and sometimes it's more relaxed. As Earth travels along the rubber band path, its distance from the Sun will change causing more or less heat to reach the Earth.
- **Precession**: As Earth spins, it wobbles on its axis. It takes 23,000 years for the Earth to complete a full wobble. To better understand precession, watch a top spin on a table. At first, it will spin along its axis because it is moving quickly. As it slows down, the top will begin to wobble about its axis just like Earth.



- **Tilt (a.k.a. Obliquity)**: Every 41,000 years, the angle of the Earth's axis relative to the plane of its orbit changes from 22.1 to 24.5 degrees.

Taking a closer look at the Milankovitch cycles, we can also understand why we experience seasons. As our tilted Earth orbits the Sun, different parts of the planet are exposed to the Sun's energy at different levels. For example, take a look at the picture on the previous page. When Earth is to the left of the Sun, the southern hemisphere is exposed to more light than the northern hemisphere. Because Earth is tilted on its axis, the Sun heats up the southern hemisphere more than the north. This gives the southern hemisphere its summer and the northern hemisphere its winter. Earth's tilt changes only slightly every 41,000 years.

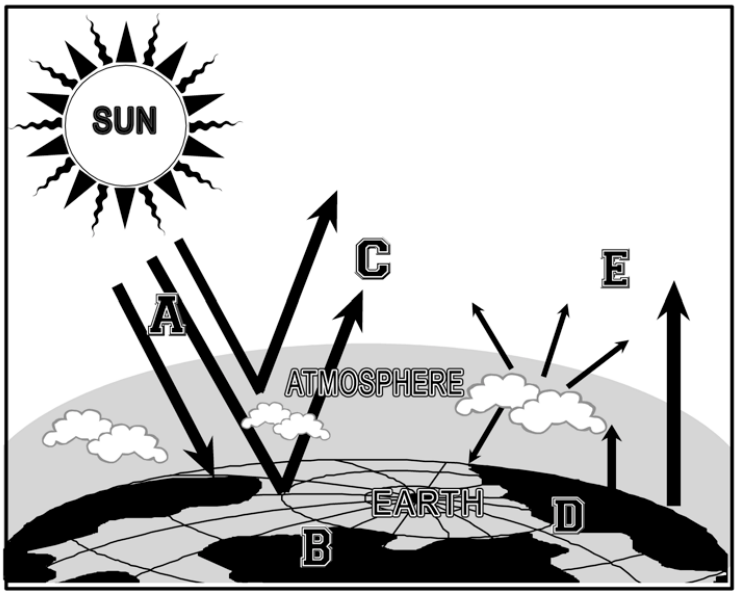
Earth's Albedo

Some of the light striking the Earth is reflected back to space. The ratio of reflected to absorbed light is known as the albedo. For Earth, approximately 30% of the Sun's light is reflected back into space while the remaining 70% is absorbed by the Earth and warms the planet. Earth's large masses of land, ice and oceans absorb different amounts of this light. Fresh snow is highly reflective and has a high albedo of 90%, while the ocean has a very low albedo and is able to absorb more energy. The albedo of the Earth is very important because it helps define the temperature of our planet.

Student Reading 1: Part 2: The Greenhouse Effect

The Greenhouse Effect

While the Milankovitch cycles affect climate change over very long periods of time, scientists have been extremely concerned that within the last 50 years, Earth's global temperatures have risen quickly. Therefore, scientists have focused their attention on the impacts of humans on the planet. The problem is that the *rate* of warming has never been so rapid. In the past, the warming periods of Earth's climate averaged 1 degree C every thousand years. Today human activities are warming the planet at a rate at least 10 times, and perhaps 40 times faster (Sussman 2006). Warming occurs when humans influence the amount of greenhouse gases produced within our atmosphere. Scientists believe that CO_2 (carbon dioxide) is the greenhouse gas that is contributing most to the recent period of global warming. This is partly because CO_2 stays so long in the atmosphere.



A. Solar radiation passes freely through the atmosphere.

B. Most of this radiation (about 70%) is absorbed by the Earth and warms the planet.

C. Some of the solar radiation (about 30%) is reflected back to space from clouds and from snow and ice on Earth.

D. The Earth emits infrared radiation in the form of heat waves.

E. Greenhouse gases like carbon dioxide, water vapor, and methane absorb some of the energy re-radiated from the Earth's surface and re-emit it in all directions. Some of the energy goes back to Earth, which warms the planet and the lower atmosphere.

To learn more about greenhouse gases and how the amount of these gases is changing due to human activities, visit this website: http://www.windows2universe.org/earth/climate/earth_greenhouse.html. Use the information provided to answer the questions on **Learning Log 1.**

LEARNING LOG 1: EARTH'S CHANGING CLIMATE

NAME_____ **DATE**_____

Using Student Reading 1, answer the following questions:

1. Describe how Earth's motions and tilt on its axis affect the seasons and weather patterns.

2. The Sun is our major source of energy. Explain how you think the Sun influences climate and weather on Earth.

3. Since the combination of the Milankovitch cycles causes changes in global climate naturally, why do scientists believe humans are causing climate change today?

4. Use the text in the Reading and the content of the National Geographic video to define the following terms and answer questions:

Climate change:

11-year solar cycle:

Milankovich cycles:

Albedo:

Axis:

Tilt:

Global warming:

5. What analogies does the instructor in the National Geographic video use to help you understand the Milankovich cycles? Why are these effective?

Using the text in Part 2 of the Reading and the information from the following website: http://www.windows2universe.org/earth/climate/earth_greenhouse.html, answer the following questions:

6. What happens to the heat that is radiated from the Earth? How do greenhouse gases affect this process?

7. What does the author report are some of the sources of greenhouse gases in the atmosphere?

8. What is expected to happen to the amount of greenhouse gases in the atmosphere during this century? Why is the amount of gases predicted to change?

WATER EXPANSION ACTIVITY INSTRUCTION SHEET

NAME_____ **DATE**_____

Research Question: What happens to the level of water in a container when the temperature of the water increases?

Your hypothesis: (If, then, because....)

Materials: small plastic water bottle, a small piece of modeling clay or playdough, a clear straw, food coloring, and a container with cold water.
Your teacher will also have an area with hot water for you to use with this activity.

1. Remove any labels on the plastic bottle as well as possible.

2. Fill the bottle half way with water.

3. Add a few drops of food coloring to the water.

4. Put the straw in the bottle, but don't let the straw touch the bottom.

5. Using the modeling clay or playdough, seal the neck of the bottle and hold the straw in place.

6. When you are ready, place the bottle in hot water. Be careful while you are near the hot water. Describe what happens.

7. Place the bottle into a container with cold water. Describe what happens.

8. How does this experiment relate to our Earth and sea level rise? Look up the term "thermal expansion" and use it in a sentence to describe one cause of sea level rise.

LEARNING LOG 2: CLIMATE CHANGE INDICATORS

NAME_____ **DATE**_____

Circle two clues from the Earth's environment that indicate that climate change is occurring. Place a check by the factor that is causing these changes.

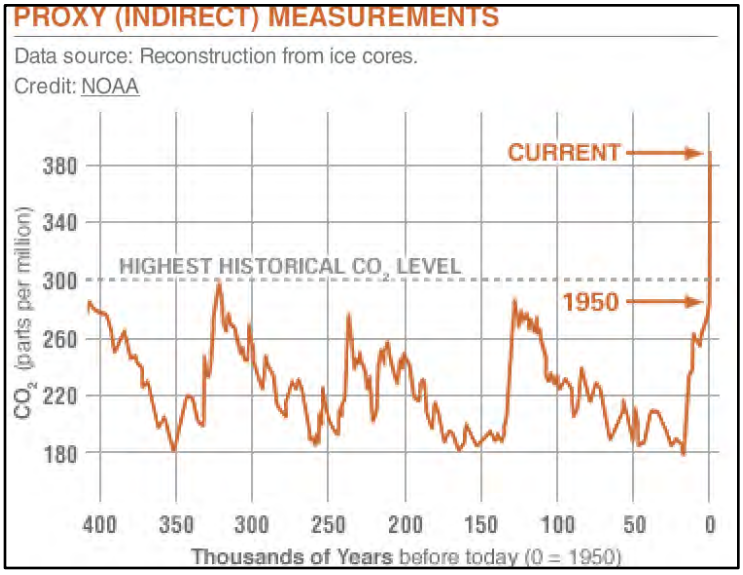
Polar ice is staying frozen. Carbon dioxide in the atmosphere is increasing.

Sea level is rising. Deforested areas are still producing lots of oxygen.

Global surface temperatures are increasing. Land mass is rising.

<u>Carbon Dioxide</u>

Carbon Dioxide is an example of a greenhouse gas that is emitted into the atmosphere through respiration and human activity. Take a look at the CO_2 graph to the right. It includes data from thousands of years ago. Use this graph to answer the following questions.



Graphs courtesy of NASA, Global Climate Change, Vital Signs of the Planet. http://climate.nasa.gov/key_indicators/

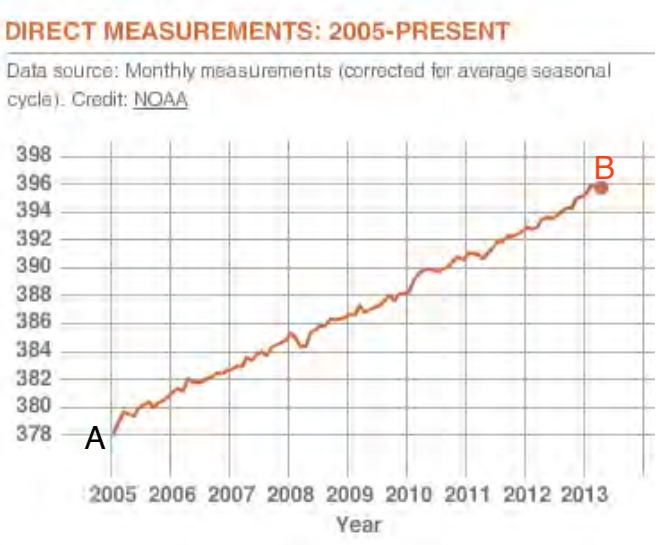
1. What was the "highest historical CO_2 level" in ppm? _____

2. What year did the CO_2 level go above this level? _____

3. What do you think caused this increase and why?

_____

Now let's take a look at CO_2 levels within the last decade. Using the graph to the right, answer the following questions.



4. What are the coordinates (x, y) at points A and B?

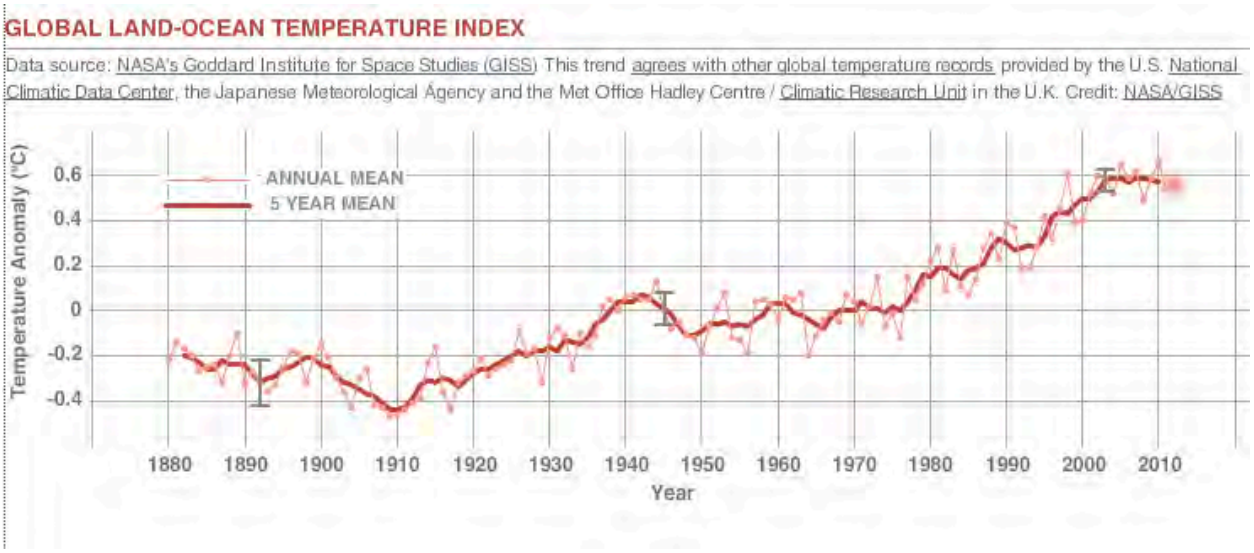
A = _____ B = _____

5. What is the slope of a line drawn between these two coordinates? [Hint: Slope = (change in x) / (change in y)]

6. Describe what you think happens to the climate when the amount of CO_2 in our atmosphere rises.

Global Surface Temperature

Global surface temperature can change for many reasons. The change in global surface temperature relative to average temperatures is known as an anomaly. The graph below shows temperature anomalies for annual and for 5 year means.



1. Using the graph above and table below, fill in the annual mean from 1990 to 2010.

Year	Temperature Anomaly (◦C)
1990	+ 0.36
1991	+ 0.35
1992	+ 0.13
1993	+ 0.13
1994	+ 0.23
1995	+ 0.37
1996	+ 0.29
1997	+ 0.39
1998	+ 0.56
1999	+ 0.32

Year	Temperature Anomaly (◦C)
2000	+ 0.33
2001	+ 0.47
2002	+ 0.56
2003	+ 0.55
2004	+ 0.48
2005	+ 0.63
2006	+ 0.55
2007	+ 0.58
2008	+ 0.44
2009	+ 0.58
2010	+ 0.63

2. What year had the greatest temperature anomaly?

3. If x = the highest temperature between 1990 and 2010 and y = the lowest temperature in this time period, what is the amount that temperature anomaly has risen? Write your equation, then solve.

4. Since 1990, how would you describe the Global Surface Temperature anomalies of the Earth?

Sea Level

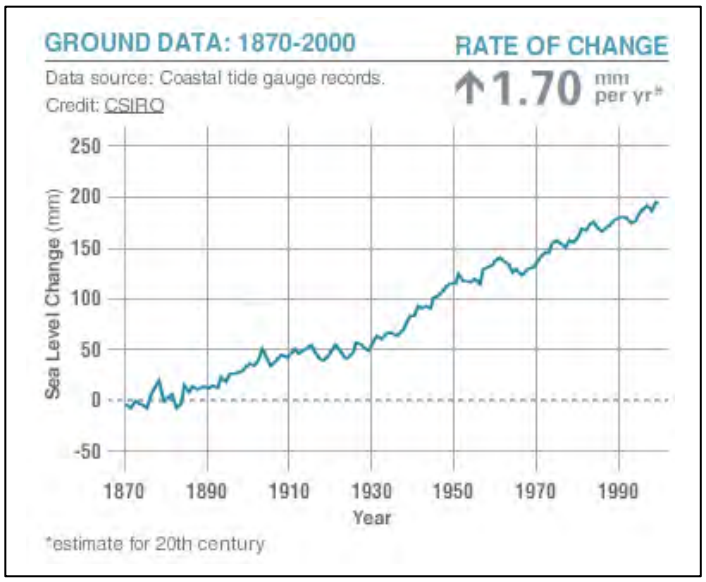
Now let's see how sea level has been affected with climate change.

1. Using the chart to the right that describes data collected for sea level between 1870 and 2000, draw a line between the data points of 1870 and 1990.

2. 2. What are the coordinates (x, y) at points A and B?

A = _____ B = _____

3. What is the slope of this line? (Hint: Slope = change in x over change in y)



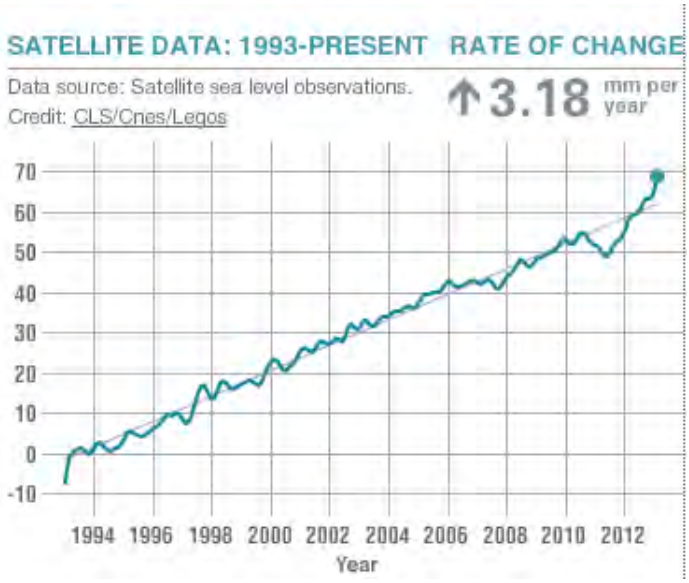
Graph courtesy of NASA, Global Climate Change, Vital Signs of the Planet. http://climate.nasa.gov/key_indicators/

Let's take a closer look at sea level data from more recent years.

4. What is the rate of change between 1993 and the present?

5. Compared to the previous Sea Level graph, does it appear that sea level has been decreasing or increasing since 1994?

6. In which Sea Level graph is sea level changing faster?



Graph courtesy of NASA, Global Climate Change, Vital Signs of the Planet. http://climate.nasa.gov/key_indicators/

The Big Picture

Compare the graphs of Carbon Dioxide, Global Surface Temperature and Sea Level. Write a reflection that focuses on how climate change is related to sea level rise on a global level.

LEARNING LOG 1: EARTH'S CHANGING CLIMATE (ANSWER SHEET)

NAME_____ **DATE**_____

Using Student Reading 1, answer the following questions.

1. Describe how Earth's motions and tilt on its axis affect the seasons and weather patterns.

As our tilted Earth orbits the Sun, different parts of the planet are exposed to the Sun's energy at different levels. For example, when Earth is to the left of the Sun (as shown in the Student Reading illustration), the southern hemisphere is exposed to more light than the northern hemisphere. Because Earth is tilted on its axis, the Sun heats up the southern hemisphere more than the north. This gives the southern hemisphere its summer and the northern hemisphere its winter. Therefore, the opposite seasons occur when Earth is to the right of the Sun. As Earth makes one complete rotation about its axis in one day, heat from the sun warms the air, land, and ocean, creating our weather. The change in temperature between cool and hot air drives winds, and wind and differences in ocean temperature and salinity drives ocean currents.

2. The Sun is our major source of energy. Explain how you think the Sun influences climate and weather on Earth.

Slight variations in the distance between the Earth and Sun, and the tilt and orientation of the earth's axis (the Milankovitch Cycles) happen with periods of thousands of years. Because of this, there are changes in the amount and distribution of energy that the Sun provides Earth causing our climate to change.
On a daily level, energy from the Sun warms different parts of Earth at different times. This causes air in the atmosphere to heat up or cool down. As different air temperatures interact with each other, they cause changes in our weather.

3. Since the combination of the Milankovitch cycles causes changes in global climate naturally, why do scientists believe humans are causing climate change today?

The main difference is in the rate of change of adding carbon dioxide to the atmosphere, where it remains for long periods of time. The global warming occurring today is happening at a much more rapid rate than past periods of global warming.

4. Use the text in the Reading and the content of the National Geographic video to define the following terms and answer questions:

Climate Change: significant changes in temperature, precipitation, wind and other weather patterns over an extended period of time, especially a change due to an increase in the average atmospheric temperature

11 - Year Solar Cycle: the periodic change in the amount of irradiation from the Sun that is experienced on Earth approximately every 11 years

Milankovitch Cycles: changes in the Earth's movement with respect to the Sun that alters the amount and distribution of solar radiation reaching Earth

Albedo: the ratio of the light reflected by a planet or satellite to that received by it

Axis: the line about which a rotating body, such as the Earth, turns

Tilt: the leaning or slant of an object

Global warming: the warming of the atmosphere most likely due to the greenhouse effect

5. What analogies does the instructor in the National Geographic video use to help you understand the Milankovich cycles? Why are these effective?

The instructor uses the analogy of a spinning top to help explain precession, at firsts the top spins along its axis because it is moving quickly. As it slows down, the top begins to wobble on its axis, just like Earth. The instructor uses his head as "Earth" and his bald spot as the top of the imaginary axis. He moves his head to show approximately how much the angle of the axis tilts. He uses a hula hoop, a tennis ball and a tangerine to demonstrate eccentricity - how the shape of the Earth's orbit around the Sun becomes more or less oval over time. These are effective because he uses familiar objects to explain new concepts.

Using the text in Part 2 of the Reading and the information from the following website: http://www.windows2universe.org/earth/climate/earth_greenhouse.html, answer the following questions:

6. What happens to the heat that is radiated from the Earth? How do greenhouse gases affect this process?

The heat waves that are re-radiated from the Earth are absorbed by greenhouse gases like carbon dioxide, water vapor, and methane. The greenhouse gases radiate some of the heat back to Earth, to another greenhouse gas molecule, or radiate back out to space.

7. What does the author report are some of the sources of greenhouse gases in the atmosphere?

Burning fossil fuels, methane from farm animals, and the release of carbon dioxide as cement is manufactured from limestone

8. What is expected to happen to the amount of greenhouse gases in the atmosphere during this century? Why is the amount of gases predicted to change?

It is expected to double because of human activities like those listed above.

LEARNING LOG 2: CLIMATE CHANGE INDICATORS (ANSWER SHEET)

NAME_____ **DATE**_____

Circle three clues from the Earth's environment that indicate that climate change is occurring.

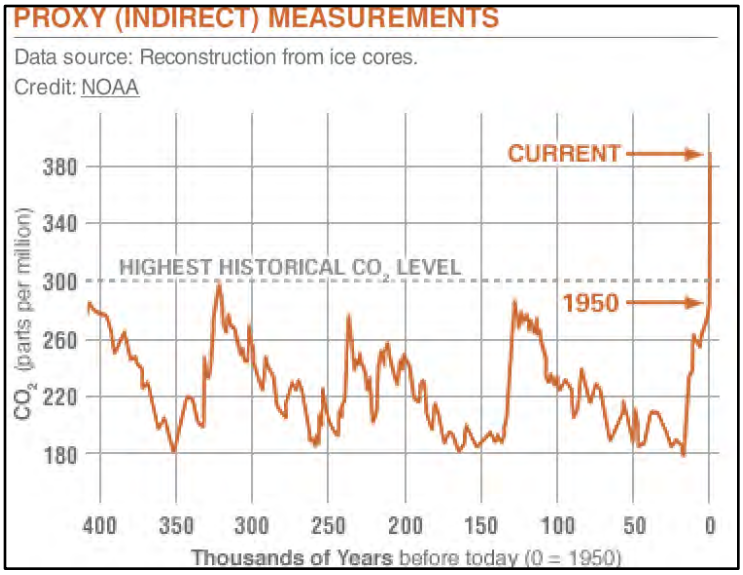
Polar ice is staying frozen. Carbon dioxide in the atmosphere is increasing.

Sea level is rising. Deforested areas are still producing lots of oxygen.

Global surface temperatures are increasing. Land mass is rising.

Carbon Dioxide

Carbon Dioxide is an example of a greenhouse gas that is emitted into the atmosphere through respiration and human activity. Take a look at the CO_2 graph to the right. It includes data from thousands of years ago. Use this graph to answer the following questions.

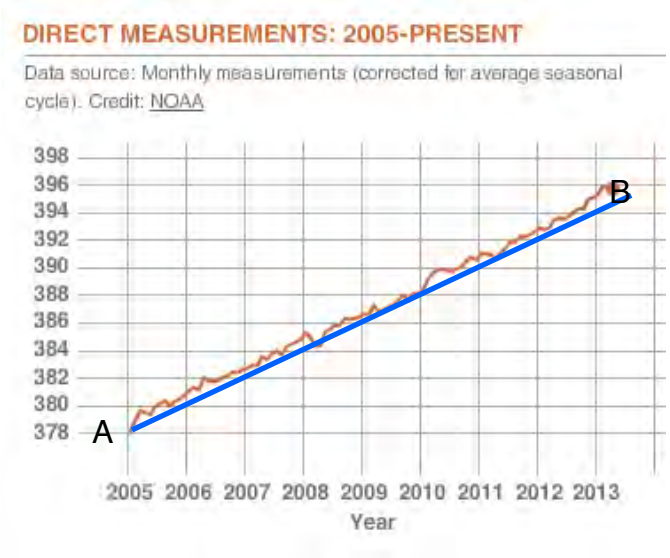


1. What was the highest historical CO_2 level in ppm? 300 ppm

2. What year did the CO_2 level go above this level? Around 1950

3. What do you think caused this increase and why? Increased use of fossil fuels

Now let's take a look at CO_2 levels within the last decade. Using the graph to the right, answer the following questions.



4. What are the coordinates (x, y) at points A and B?

A = (2005, 378) B = (2013, 396)

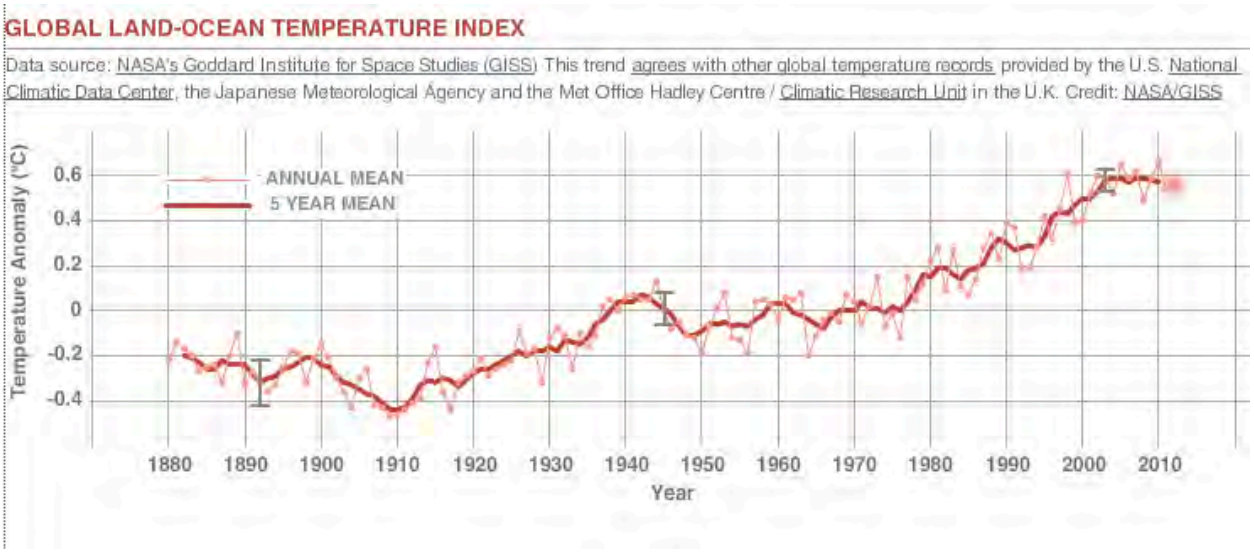
5. What is the slope of a line drawn between these two coordinates? [Hint: Slope = (change in x) / (change in y)] Slope = (2013 - 2005)/(396-378) = 8/18

6. Describe what you think happens to the

climate when the amount of CO_2 in our atmosphere rises. The temperature of the atmosphere increases.

Global Surface Temperature

Global surface temperature can change because of many reasons. The change in global surface temperature relative to average temperatures is known as an anomaly. The graph below shows temperature anomalies.



1. Using the graph above and the table below, fill in the data points from 1990 to 2010.

Year	Temperature Anomaly (◦C)
1990	+ 0.36
1991	+ 0.35
1992	+ 0.13
1993	+ 0.13
1994	+ 0.23
1995	+ 0.37
1996	+ 0.29
1997	+ 0.39
1998	+ 0.56
1999	+ 0.32

Year	Temperature Anomaly (◦C)
2000	+ 0.33
2001	+ 0.47
2002	+ 0.56
2003	+ 0.55
2004	+ 0.48
2005	+ 0.63
2006	+ 0.55
2007	+ 0.58
2008	+ 0.44
2009	+ 0.58
2010	+ 0.63

2. What year had the greatest temperature anomaly? 2010

3. If x = the highest temperature between 1990 and 2010 and y = the lowest temperature in this time period, what is the amount that temperature anomaly has risen? Write your equation, then solve.

x = +0.63, y = +0.13 x - y = n 0.63 - 0.13 = 0.50

The temperature anomaly has risen 0.40◦ C between 1990 and 2010.

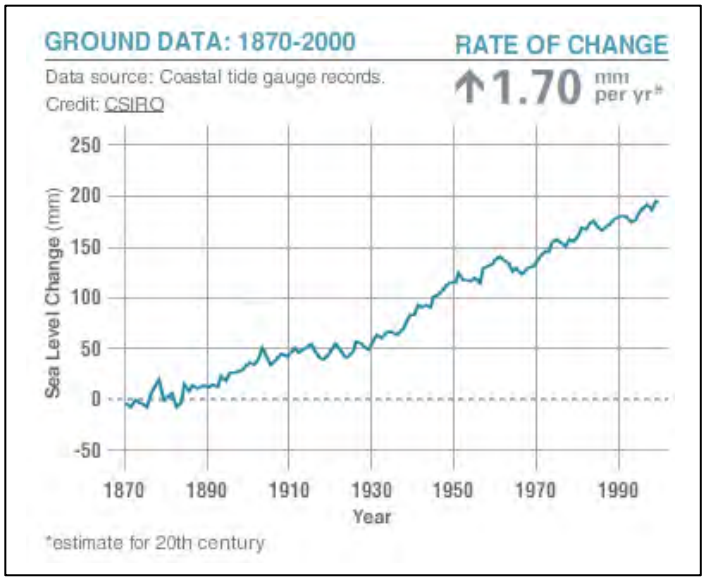
4. Since 1990, how would you describe the Global Surface Temperature anomalies of the Earth?

Global Surface Temperature anomalies have been steadily rising since 1990.

Sea Level

Now let's see how sea level has been affected with climate change.

1. Using the chart to the right which describes data collected for sea level between 1870 and 2000, draw a line between the data points of 1870 and 1990.



2. What are the coordinates (x, y) at points A and B?

A = (1870, 0) B = (1990, 175)

3. What is the slope of this line? (Hint: Slope = change in x over change in y)

Slope = (1990 - 1870)/(175 - 0) = 120/175 = 24/35

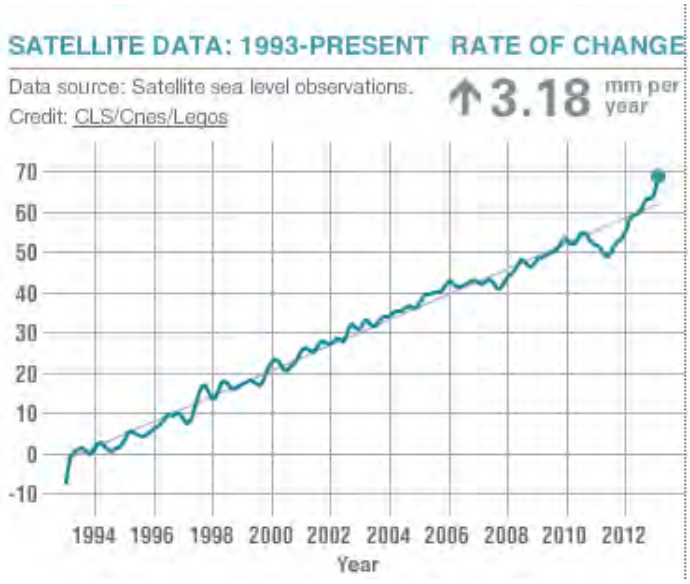
Let's take a closer look at sea level data from more recent years.

4. What is the rate of change between 1993 and present?
   Increasing 3.18 mm per year

5. Compared to the previous Sea Level graph, does it appear that sea level is decreasing or increasing?
Sea level is increasing.

6. In which Sea Level graph is sea level changing faster?

In the graph to the right, the rate of change is increasing at 3.18 mm/yr compared to the first graph that had a rate of change of increasing 1.70 mm/yr. Therefore, sea level is changing faster in the second graph, representing more recent time.



The Big Picture

Compare the graphs of Carbon Dioxide, Global Surface Temperature, and Sea Level. Write a reflection that focuses on how climate change is related to sea level rise on a global level.

Changes in carbon dioxide levels, global surface temperatures, and sea level are indicators of climate change. The graphs all reflect similar information in that as carbon dioxide is added to our atmosphere, global surface temperatures increase, leading to the heating of our oceans and the melting of land ice. This in turn, raises global sea level.

Water Power

How is climate change related to local sea level rise?

Activity at a Glance

Students work in groups to map locations of significant landmarks in their school's area. They add topographic lines to the map to indicate changes in elevation. Using their topographic map as a guide, groups create a 3-D model of their school's area to investigate the impacts of sea level rise.

Key Concepts

- Topographic maps represent a three-dimensional surface that is drawn to scale in a two-dimensional format. Information, such as elevations and steepness of terrain, can be derived from these maps.
- A location's profile can be drawn from a topographic map by charting the length and rise of an area.
- A three-dimensional model created from a topographic map is useful to demonstrate different scenarios of sea level change, such as global sea level rise and tsunamis, and the impacts on landmarks.
- Sea level rise will cause significant changes in coastal communities including impacts on society, the economy, environment, and cultural sites.

Skills

Graphing, collecting and interpreting data, formulating and testing hypotheses, modeling, interpreting maps

Assessment

Students:

- Complete a topographic map of the school's area and illustrate specific elevations and important landmarks.
- Create a three-dimensional model using information from a topographic map.
- Use a three-dimensional model to analyze different scenarios for sea level rise, and write a reaction paper about the impact of sea level rise on their community.

Hawai'i State Standard Benchmarks

Science 1: The Scientific Process - Scientific Inquiry

- **SC.8.1.1** Determine the link(s) between evidence and the conclusion(s) of an investigation.
- **SC.8.1.2** Communicate the significant components of the experimental design and results of a scientific investigation.

Science 2: Nature of Science - Science, Technology and Society

- **SC.8.2.1** Describe significant relationships among society, science, and technology and how one impacts the other.

Science 5: Life and Environmental Sciences - Biological Evolution

- **SC.8.5.1** Describe how changes in the physical environment affect the survival of organisms.

Common Core Standards

Math: Expressions and Equations - Connections Between Proportional Relationships, Lines and Linear Equations

- **EE.8.5** Graph proportional relationships, interpreting the unit rate as the slope of the graph. Compare two different proportional relationships represented in different ways.

Language Arts: Reading

- **R.8.4** Determine the meaning of words and phrases as they are used in a text, including figurative and connotative meanings; analyze the impact of specific world choice on meaning and tone, including analogies or allusions to other texts.

Suggested Timeframe

Five 45-50-minute class periods

Day 1: Introduce topographic mapping; Learning Log 3
Days 2 - 3: Topography and 3-D modeling; Making models from topographic maps
Day 4: Setting up scientific inquiry; Learning Log 4
Day 5: Conduct inquiry with models and summarize

Materials

Provided

- Learning Log 3: Topographic Maps
- Learning Log 4: Investigating Local Impacts of Sea Level Rise
- Instructions: Making 3-D Models

For You to Provide

- Topographic map of school's area*
- Projector
- Permanent markers
- Newspaper
- Scissors
- Container for water
- Foil or glass pans (one per model)

Materials for each option A model

- Masking tape
- 2 rulers
- Modeling clay
- Large piece of paper
- String
- Flashlight
- Creative objects (miniature buildings, cars, etc.)

Materials for each option B model

- Corrugated cardboard
- Materials for papier-mâché (glue or flour, newspaper)

* Topographic maps for selected schools in tsunami inundation zones are provided on the project website. (See Getting Ready.)

Getting Ready

✓ Check the project website: http://www.discovertsunamis.org/ Click on the Classroom Lessons tab. Check the Appendices for a topographic map of your school's area. If needed, additional maps can be purchased online or downloaded from the Internet.

✓ Print copies of the topographic map and Learning Logs for each student.

✓ Print copies of the topography map vocabulary activity to accommodate groups of 3 to 4 students. Print the vocabulary words on a paper that is a different color than the definitions and cut the vocabulary words page in half.

✓ Review the Instructions for Making 3-D Models, select option A or B, and gather materials as needed. See http://www.dltk-kids.com/type/how_to_paper_mache.htm for assistance with preparing papier-mâché.

Vocabulary

Contour line: a line that connects points of equal elevation
Contour interval: the change in elevation between one contour line and the next
Elevation: height above sea level
Index contour: every fifth line that is darkened on a contour map
Landmark: a prominent or conspicuous object on land that serves as a guide
Scale: a proportion used to determine the actual distance between two points on a map
Topography: the detailed mapping or charting of the features of a relatively small area

Teacher Background Information

If sea level rise measurements continue as predicted in Hawai'i, it is estimated that by the end of this century, sea level will rise 3.3 ft (1 m) (Fletcher 2010). This would be catastrophic for many areas in our state. For example in Waikīkī, the Ala Wai Boat Harbor, Hilton Hawaiian Village lagoon, banks of the Ala Wai Canal, and most of the Ala Wai Golf Course will be submerged. Magic Island will be an actual island! Low-lying areas on other islands will also be submerged at high tide and shorelines will erode (Leone 2007).

Topographic maps are useful tools for students to visualize the potential impact of sea level rise in Hawai'i. Topographic maps represent a three-dimensional surface that is drawn to scale on a flat sheet of paper. The contour lines indicate different elevations. The most common topographic maps use the measurement of 7.5 minute 1:24,000 scale in which 1 inch represents 2,000 feet (USGS 2008).

Using these types of maps, students can derive information about the natural environment and determine the steepness of a mountain or the flatness of a plain. They can see why urban and rural areas are located where they are and how society has adapted to the environment's physical characteristics. They can also determine how topography affects where the rising sea level will have an impact in different areas, including how various landmarks will be affected.

Knowing the impacts of sea level rise can help society plan for the future. In this lesson, students will take topographic maps a step further and create a three-dimensional model. They will test hypotheses about how sea level rise will affect local landmarks and how the local topography will affect the potential impact of sea level rise.

Teaching Suggestions

Part 1: Topographic Mapping

1. **Discuss the lesson's focus question with the class.**
   - How is climate change related to local sea level rise?
   - Discussion Questions
     - Are there significant landmarks surrounding the school that need to be protected from sea level rise? How can we determine this?
     - Are there significant land features near the school that could affect the impact of sea level rise? How would they affect the impact of a rising sea?
     - What do you predict the impact will be if sea level rises in the area near our school by 1 foot, 3 feet, or 5 feet? Explain your thinking.

2. **Introduce the students to topographic maps.**
   - Distribute a topographic map of your school's area to each student.

- Project the topographic map so that the entire class can see it.
- Point out the topographic lines that are used in the map and explain how each line represents a specific elevation.
- Point out the information in the distance scale.

3. Introduce the students to vocabulary used in topographic maps.
- Divide the class into groups of 3 to 4 students.
- Distribute materials for the topographic map vocabulary activity and **Learning Log 3** to each group.
- Have students cut out the words and the definitions and work together to match them.
- Give the class 15 minutes to match the vocabulary word with its meaning and complete the first part of Learning Log 3.

4. Continue exploring the topographic map with the class.
- Locate your school on the map, and as a class, identify the topographic features in the area (ridges, dunes, bluffs, etc.).
- Identify the locations of significant landmarks in the community such as large old trees, historic buildings, and cultural sites.
- If you are able to project an interactive online map (such as in Google Map), toggle between the topographic map and the satellite view to help students get a better understanding of their location and the surrounding features and landmarks.
- Have students record the topographic features and landmarks on their individual maps.

Part 2: Topography and 3-D Modeling

5. Introduce students to graphing elevations using information from topographic maps and have students complete Learning Log 3.
- Ask students to think about how they could draw a profile of an elevation on a graph if they knew its length and rise (height).
- Discuss their ideas and then draw a graph on the board with the distance on the x-axis and the elevation on the y-axis.
- Discuss the relationship between rise and distance.
- Choose a feature in your area and challenge students to draw its topographic profile. Provide assistance as needed to show students how this is done. Include sea level in your illustration.
- Using their own topographic maps, have each student complete **Learning Log 3** and draw a profile of the topography around their school.

6. **Provide materials for students to construct 3-D models using the instructions for option A or B.**
   - Divide the class into groups of three or four students.
   - Distribute the materials that each group will need to create a three-dimensional model**.**
   - Hand out the appropriate **instruction sheet** for creating models and ask students to follow the directions.

Part 3: Conducting Investigations

7. **Have students conduct an investigation to demonstrate the impact of sea level rise in their community.**
   - Using **Learning Log 4**, have groups record two hypotheses about the impact of sea level if it were to rise 3.3 ft (1 m) as predicted by 2100:
     - How will sea level rise affect local landmarks?
     - How will local land features affect the potential impact of sea level rise?
   - Challenge students to use their models to test their hypotheses.

8. **Add sea level to models and have students record their observations on Learning Log 4.**
   - Have students gently pour water into their model containers and stop at the sea level mark.
   - Discuss the accuracy of their models. Is sea level where it should be according to their maps?
   - Have students gradually increase sea level by adding water to their containers and use a ruler to determine the increased height. Have them raise sea level to the equivalent of 1 m on their models and record their data on **Learning Log 4**.
   - Draw special attention to the landmarks that were previously determined as important areas to protect. Discuss their results.
     - Do land features affect the impacts of sea level rise?
     - According to your initial hypotheses, are areas threatened or protected from sea level rise?
     - What do you predict would happen if tides or storms were included in the model?

9. **Have students model the potential level of a tsunami in the area.**
   - Scoop out water to return sea level back to the initial stage. Place the water into an empty container.
   - Using slight force, dump the water back into the ocean area and have students carefully watch how far the water goes inland.

- Additional waves could be created by having a student wave his/her hands in the water, causing it to flood the land.
- Have students record their observations on **Learning Log 4**.
- Ask students to clean up and recycle as many materials as possible.

10. Have students summarize their findings and write a reaction paper.

- Ask students to reflect on the potential social, environmental, economical and other impacts that sea level rise will have on their communities as demonstrated by their models.

EXTENDING THE LEARNING

NGSS:

Have students determine how forecasts for sea level rise should inform the development of technologies to mitigate the effect on their community.

- Have students simulate changes in tides and sea levels on NOAA's Data in the Classroom website (http://www.datainthecclassroom.org/content/sea-level/tide-model.html). Adjust the measurement in the "Long-term Change Sea Level Rise" box and click on the box on the far right to activate the scenario.

- Have students conduct in-depth investigations of social, economic, and environmental impacts to an area affected by sea level change. Use online topographic maps and toggle between layers of information about human populations, urban areas, environmental resources (www.arcgis.com/home/webmap/viewer.html). Have students research articles and write a report about these impacts. In addition to the measurements of elevation, students can graph, diagram, and model the bathymetry of the ocean and identify reefs and other marine resources.

References

Fletcher, Charles H. *Hawai'i's Changing Climate Briefing Sheet, 2010*. Honolulu: University of Hawai'i Sea Grant College Program. Center for Island Climate Adaptation and Policy (ICAP). 2010.

Leone, Diane. "The Drowning of Hawaii." *Honolulu Star Bulletin*, September 23, 2007. Accessed October 4, 2011. http://archives.starbulletin.com/2007/09/23/news/story01.html.

U.S. Geological Survey. "Topographic Mapping." Last modified February 25, 2008. Accessed October 14, 2011. http://egsc.usgs.gov/isb/pubs/booklets/topo/topo.html.

Resource

You can purchase topographic maps through the U.S. Geological Survey (USGS) online store at http://www.store.usgs.gov

LEARNING LOG 3: TOPOGRAPHIC MAPS (ANSWER SHEET)

NAME_____ **DATE**_____

TOPOGRAPHIC MAP VOCABULARY

Define the following words:

contour line: a line that connects point of equal elevation

contour interval: the change in elevation between one contour line and the next

elevation: height above sea level

index contour: every fifth line that is darkened on a contour map

landmark: a prominent or conspicuous object on land that serves as a guide

scale: a proportion used to determine the actual distance between two points on a map

topography: the detailed mapping or charting of the features of a relatively small area

Complete the following sentences to demonstrate your understanding of topographic maps:

1. The vertical distance of the contour intervals in this topographic map are (refer to info near scale, i.e., 20 ft).
2. The distance scale in this topographic map is measured in (i.e., feet, miles, km).
3. For every _____ on my ruler, this equals a distance of _____ on my topographic map.
4. The elevation at my school is _____.

LEARNING LOG 3: TOPOGRAPHIC MAPS (ANSWER SHEET)

5. The ocean's distance from my school is approximately _____.

6. The elevation of the highest contour line on this topographic map is _____.

7. The elevation of the lowest contour line on this topographic map is _____.

8. Convert the measurements in questions 1 through 7 into metric units.

   Q1. _____ Q2. _____ Q3. _____, _____

   Q4. _____ Q5. _____ Q6. _____

   Q7. _____

9. The ocean is located to the _____ (direction) of my school.

10. The closer the contour lines are on this map, the steeper the slope. The farther the contour lines are, the flatter the slope.

11. A closed line on the topographic map indicates a contour line.

Draw a straight line that runs through your school and includes sea level and the highest elevation on your map. Draw an x and y axes and sketch a profile of this line below.

LEARNING LOG 3: TOPOGRAPHIC MAPS

NAME_____ **DATE**_____

TOPOGRAPHIC MAP VOCABULARY

Define the following words:

contour line:

contour interval:

elevation:

index contour:

landmark:

scale:

topography:

Complete the following sentences to demonstrate your understanding of topographic maps:

1. The vertical distance of the contour intervals in this topographic map are _____.
2. The distance scale in this topographic map is measured in _____.
3. For every _____ on my ruler, this equals a distance of _____ on my topographic map
4. The elevation at my school is _____.

5. The ocean's distance from my school is approximately _____.

6. The elevation of the highest contour line on this topographic map is _____.

7. The elevation of the lowest contour line on this topographic map is _____.

8. Convert the measurements in questions 1 through 7 into metric units.

Q1. _____ Q2. _____ Q3. _____, _____

Q4. _____ Q5. _____ Q6. _____

Q7. _____

9. The ocean is located to the _____ (direction) of my school.

10. The closer the contour lines are on this map, the _____ the slope. The farther the contour lines are, the _____ the slope.

11. A closed line on the topographic map indicates a _____.

Draw a straight line that runs through your school and includes sea level and the highest elevation on your map. Draw an x and y axes and sketch a profile of this line below.

TOPOGRAPHIC MAP VOCABULARY ACTIVITY

Cut out the words and match them to the definitions.

contour elevation scale

contour interval landmark

index contour topography

TOPOGRAPHIC MAP VOCABULARY ACTIVITY

Cut out the words and match them to the definitions.

contour elevation scale

contour interval landmark

index contour topography

a line that connects point of equal elevation

the change in elevation between one contour line and the next

height above sea level

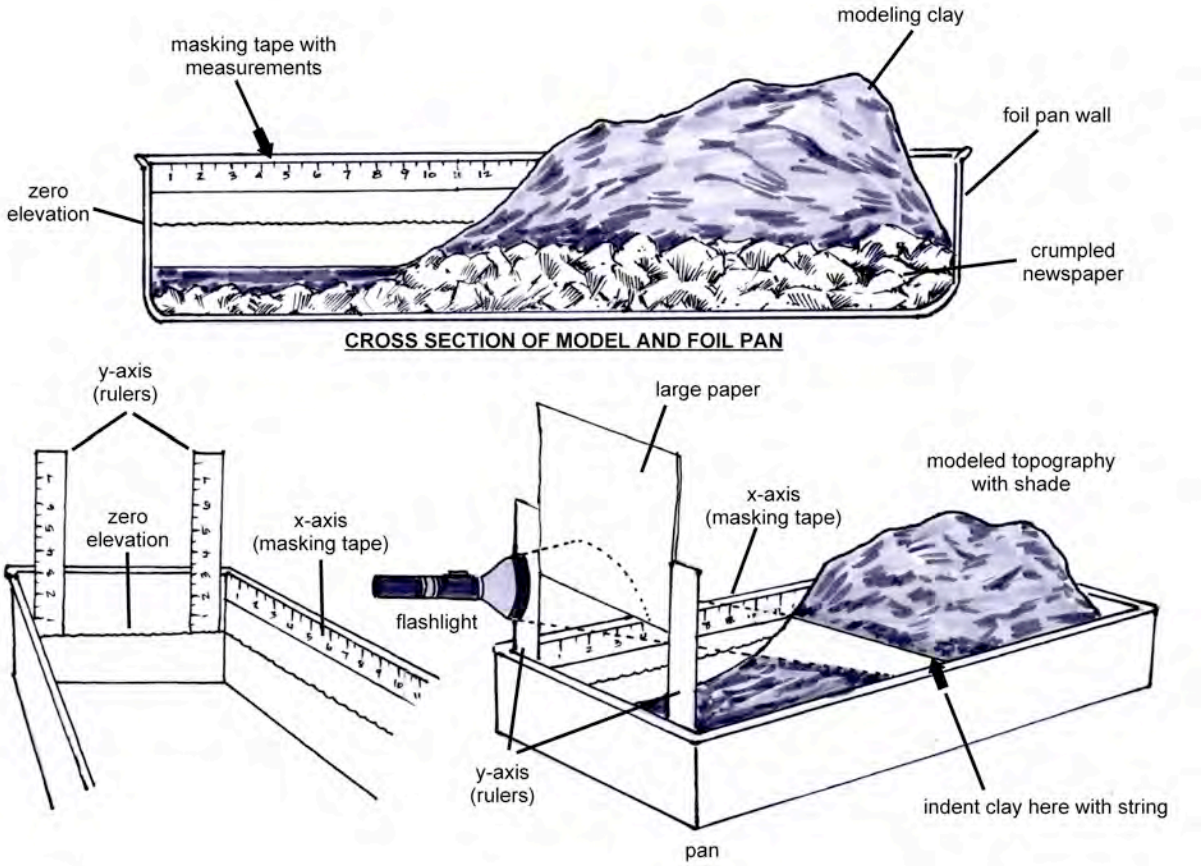
every fifth line that is darkened on a contour map

a prominent or conspicuous object on land that serves as a guide

a proportion used to determine the actual distance between two points on a map

the detailed mapping or charting of the features of a relatively small area

INSTRUCTIONS: MAKING A 3-D MODEL - OPTION A



Note: Use a large <u>clear</u> container rather than a foil pan if you want to have a better side view of the model.

1. On a flat surface, spread out two strips of masking tape and transfer measurements from the 12" ruler to each tape. For each centimeter on the ruler, have it equal one foot on the topographic map. These measurements should be comparable to those used on the distance key of the topographic map.
2. Determine approximately where the model should be placed in the container or pan. Depending on the location of your school and landmarks, you may want to have it cover approximately half to two-thirds of the pan.
3. Place each masking tape strip along the length of each side of the pan. The strips should be positioned at the top portion of the inner wall. This will be similar to the x-axis of the profile chart and will be used to determine the land areas.
4. Crumple newspaper into balls and use it to form the base of the model. Place the crumpled newspaper along the end of the pan that was determined to be the land area.
5. Cover the newspaper with a thin layer of modeling clay and create the approximate height in areas where the elevation increases. This will be adjusted later.

6. Determine where a zero elevation (sea level) is located. Tape each ruler vertically to the inner portion of the pan and position the ruler so that the beginning of its measurement is where sea level should be. This will be similar to the y-axis of the profile chart and will be used to determine the location of elevations on the model.

7. Using your topographic map, transfer elevations to the model.
   - Position the large piece of paper so that each end corresponds with the same measurements on each ruler.
   - Have one of your team members shine a light on the ocean side of the paper and another use a string to follow the shadow and indicate each elevation.
   - Press the string into the modeling clay and leave an imprint.
   - Note the elevation in the modeling clay.
   - Add or remove clay to make adjustments to accurately depict the elevations of areas.
   - Continue this process until all elevations are complete.

8. You may want to add objects to your model to indicate locations of different landmarks. If possible, use 3-dimensional objects.

Instructions: Making 3-D Model – Option B

Create a 3-D model from a topographic map of your community and surrounding area.

1. Use an extra copy of the topographic map and cut out the biggest circle or contour line on the map.

2. Place that contour on corrugated cardboard and cut it out.

3. Repeat this procedure for each of the contour lines on the map.

4. Then stack the layers and glue each piece to the one below it.

5. To give the model a smoother look, papier-mâché 1/2-inch strips of newspaper to cover the cardboard pieces. To papier-mâché, mix glue and water in a container and soak the strips of newspaper, then apply to evenly cover the model

6. Once the papier-mâché dries paint and label your model. Paint the ocean and the land surfaces. When these dry, use a permanent marker to draw the contour lines.

7. Mark the location of your school and any significant landmarks on your model.

8. Paint a layer of glue over all sides of the model to seal it. Then let it dry.

9. Place your model in a clear box or pan so that you can add water to simulate rise in sea level and potential impacts on your community.

See http://www.dltk-kids.com/type/how_to_paper_mache.htm for assistance with preparing papier-mâché.

LEARNING LOG 4:
LOCAL IMPACTS OF SEA LEVEL RISE

NAME_____ **DATE**_____

Hypothesis 1: Write your hypothesis about how sea level rise will affect local landmarks.

Hypothesis 2: Write your hypothesis about how local topography will affect the potential impact of sea level rise.

Method: Describe the method your group will use to collect your data and the variables that you need to control. Your method should not describe how to do the experiment (example, use clay, ruler, etc.). Rather, it should focus on what you will do to test your hypothesis.

Observations: Summarize key observations and notes from the model.

Learning from Nature's Clues

What environmental clues provide evidence for climate change in Hawai'i?

Activity at a Glance

Students gather information about scientific evidence for indicators of climate change in Hawai'i. They then conduct interviews with family and/or community members to gather information about environmental changes observed over time. Using this information, they create charts, timelines, and inventories and draw conclusions about possible links between local observations and climate change indicators.

Key Concepts

- People in the community can provide valuable information about changes in climate and ocean conditions.
- Conducting oral interviews with people in the community requires preparation and adherence to certain protocols in order for an interviewer to obtain the information intended.
- Patterns normally found with marine organisms and their environments eventually change in response to climate change and sea level rise.

Skills

Communicating orally, critical listening, interviewing, recording, reflecting

Assessment

Students:

- Describe the links between evidence and conclusions regarding environmental changes over time and climate change.
- Describe the effects of ocean and shoreline changes on the survival of marine life.
- Conduct interviews with family members, kūpuna, fishers or other community members familiar with the ocean and document their observations.

Suggested Timeframe

Five 50-minute class periods

Day 1: K-W-L chart, student research on climate change indicators

Hawai'i State Standard Benchmarks

Science 1: The Scientific Process - Scientific Inquiry

- **SC.8.1.1** Determine the link(s) between evidence and the conclusion(s) of an investigation.

Science 5: Diversity, Genetics, and Evolution - Biological Evolution

- **SC.8.5.1** Describe how changes in the physical environment affect the survival of organisms.

Common Core Standards

Language Arts: Speaking and Listening - Comprehension and Collaboration

- **SL.8.1** Engage effectively in a range of collaborative discussions (one-on-one, in groups and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.

Nā Honua Mauli Ola

'Ike Pilina - Relationship Pathway

- **NHMO.1.3** Interact with kūpuna in a loving and respectful way that demonstrates an appreciation of their role as culture bearers

Day 2: Review Student Reading on coral bleaching and cause and effect relationships
Day 3: Learning Logs 5 and 6
Day 4: Classroom interview and continue Learning Log 5 (Note: The interviewing and data collection process may need to be expanded to cover additional time, as needed.)
Day 5: Summary discussion for Learning Log and review K-W-L chart

Materials

Provided
- Student Reading 2
- "Hawai'i's Changing Climate Briefing Sheet"
- Learning Log 5: Community Observations
- Learning Log 6: Interview Guidelines
- Group Charts

For You To Provide
- Chart paper
- Pens
- Post-its in 2 different colors

Getting Ready

✓ Set up a K-W-L chart using the chart paper and Post-its in the front of the classroom.
✓ Make copies of the Student Reading, Learning Logs and Group Charts.
✓ Make six copies of "Hawai'i's Changing Climate Briefing Sheet" (provided in the Appendix).
✓ Invite one or two guest speakers to visit your class and speak about their observations of changes in the environment related to climate change indicators. These speakers could be fishers, government officials, or people who have lived near the ocean for long periods of time.
✓ Preview the Reef Check Hawai'i webpage: http://www.reefcheckhawaii.org/eyesofthereefBleach.htm to orient students to examples of changes in marine life due to changing ocean conditions.

Vocabulary

Climate: the average weather conditions in a location or region over time
Ocean acidification: the process where seawater becomes more acidic due to increased CO_2 dissolved in the water
Weather: the conditions in the atmosphere at a particular time and place, including temperature, wind, and humidity
Zooxanthellae: the algae that live within the tissues of coral polyps and produce food for the coral through photosynthesis

Teacher Background Information

There are many indicators of our changing climate such as rising air and ocean temperatures, changes in migration patterns of animals, and changes in currents, rainfall and storm intensity. Clues such as changes in the availability of marine resources during different seasons and the abundance of plants and animals in specific areas are all ways that we can detect changes in our climate. For a description of indicators of climate change in Hawai'i, see Fletcher, Charles H. "Hawai'i's Changing Climate Briefing Sheet 2010" provided in the Appendix. This briefing sheet summarizes changes to Hawai'i's climate including changes in air temperature, rainfall and stream flow, storm intensity, sea level, sea surface temperatures, and ocean acidification.

One example of an environmental response to increased sea surface temperature is coral bleaching. Marine researchers at the University of Hawai‘i have measured sea surface temperatures at Station ALOHA, 62 mi (~100 km) north of Kahuku Point on O‘ahu. They have found that the sea surface temperature is rising at a rate of 0.22° F (0.12° C) per decade. While large-scale bleaching events have not posed a major problem for Hawai‘i, with projected rates of water temperature increase, continued warming could lead to more bleaching events (Fletcher 2010).

The corals appear "bleached" when they lose zooxanthellae--the algae that live within the tissues of the coral polyps and produce food for the coral through photosynthesis. Since corals thrive in a narrow band of warm water temperatures, from about 77° F to 84° F (25° C to 29° C), even a slight rise in ocean temperatures can harm them. This is especially noticeable in El Niño years when ocean temperatures are warmer. El Niño are warm surface currents that occur every three to eight years in the Pacific. If conditions are right in Hawai‘i, such as warm temperatures and low winds in bays and lagoons, there can be large-scale bleaching of corals like there was in the late summer of 1996 and again in 2002 (Jokiel 2004).

The use of a calendar that focuses on cyclical patterns related to our seasons can give us a glimpse of what an area's marine resources are and how they are used within the Hawaiian culture. This seasonal events calendar provides a general picture of important cultural, environmental and socio-economic periods throughout the year. An excellent example of this is the Hawaiian moon calendar. During certain times of the year, Hawaiians planted specific plants or fished for specific fish. They were also very observant of the life cycles of plants and animals and collected responsibly.

Timelines help communities examine both natural and human-induced changes including past trends, actions, problems and achievements that have changed shorelines, contributed to climate change and impacted sea level. Timelines are helpful for people to understand present attitudes and actions that have been taken. A timeline perspective allows for reflection when moving toward the next step of projecting future actions (McFadzien, et. al. 2005).

Hawaiian kūpuna (elders) and people with a close relationship to the natural world often know how plants and animals respond to their environment. Hawaiians developed an intimate knowledge about plants and animals, weather, and ocean conditions, and many keep this tradition and pass this information on to their next generation. Conducting an inventory of plants and animals and changes in their life cycles along with changing weather or ocean conditions can provide clues about our changing climate.

Climate change is happening all around us and as an island people, we need to pay attention to the clues to change and what the implications are for our future. In this lesson, students will explore how these clues in nature connect to overall indicators of climate change in Hawai‘i.

Teaching Suggestions

Part 1: Introduction

1. **Introduce the lesson's focus question to the class. During the discussion, complete the K-W-L chart.**
   Focus Question: *What environmental clues provide evidence for climate change in Hawai‘i?*
   - Review what students learned in the first lesson about increases in carbon dioxide and rising land and ocean temperatures.
   - Ask students to brainstorm something that they know (K) and what (W) they would like to know about sea level rise and changes in local climate and ocean conditions over time.
   - Have students write their answers on Post-its and place them in the appropriate K or W column.

2. **Divide the class into six research groups to discover how various indicators of climate change in Hawai‘i are changing over time.**
   - Explain that scientists have documented the following indicators of climate change in the Hawaiian Islands:
     - ✓ Surface air temperature
     - ✓ Rainfall and stream discharge
     - ✓ Rain intensity
     - ✓ Sea level
     - ✓ Sea surface temperature
     - ✓ Ocean acidification
   - Have students predict how each of these indicators is changing (increasing or decreasing) and then ask them to conduct research.
   - Assign an indicator to each of the six groups. Distribute a copy of “Hawai‘i’s Changing Climate Briefing Sheet” to each group.
   - Ask team members to read about their indicator, summarize how it is changing, and go online to find additional information. (Note additional information on these indicators is provided in Gr. 6 Student Readings in lessons 3 and 4.)
   - Ask teams to report their findings and have all students take notes about each indicator and trends that they see.

3. **Focus on the sea surface temperature indicator with an example provided in Student Reading 2 on Coral Bleaching.**

- Distribute the Reading and ask students to diagram the causes and effects of coral bleaching.
- Have pairs of students go to the Reef Check Hawai‘i website: http://www.reefcheckhawaii.org/eyesofthereefBleach.htm and closely read the text to answer the questions provided on the Reading.
- Discuss their responses and how human activities can indirectly impact the health of our coral reefs.
- Make a distinction between impacts that are most likely due to increased ocean temperatures from climate change and other human impacts such as soil erosion into the ocean due to development.

4. Review Learning Log 5 with the class. Have students determine which climate change indicators could link with the examples provided.

- Challenge students to conduct interviews with community members to gather more evidence of changing climate and ocean conditions.
- Relate that the goal of each interview will be to gather information about local environmental changes that could be related to climate change and sea level rise. Explain that the interview questions that they will formulate should relate to the following four different categories:

    - *Calendar of seasonal observations*: A documentation of regular cyclical/seasonal periods that occur within the environment and community and changes in those cycles.
    - *Timeline of events*: A record of significant natural and human events (such as construction of seawalls, introduction of new technology, introduced marine species, tsunamis and other natural hazard events) that have influenced the nearshore area in the community.
    - *Inventory of marine animals and plants*: A summary of changes observed in marine life over time.
    - *Other additional information*.

5. Divide the class into groups of 4 to 5 students and distribute Learning Log 6.

- Discuss and record possible questions that should be asked during each interview.
- Prepare students on how to conduct an interview using the information listed in **Learning Log 6** and have them complete it.

Part 2: Conducting Interviews

6. **Have a guest speaker(s) visit the class and address the lesson's focus question.**
   - Ask the speaker to speak generally about his/her observations of changes in ocean conditions including changes in marine life.
   - Give students an opportunity to ask some of their pre-determined questions.
   - Thank the speaker for joining the class.
   - After the speaker has exited, review the interview process with students.

7. **Assign Learning Log 5 as homework and have each student conduct an interview and record the information.**

8. **Reconvene the groups and have them share information collected during their interviews. In their groups, have them complete Group Charts for each category.**
   - *Calendar of seasonal observations*: Use provided Group Chart.
   - *Timeline of events*: Have students write their event information on Post-its. Use one color for natural events. Use another color for human events. Each Post-it should contain only one event and year. Once completed, have them place each Post-it according to a timeline on chart paper.
   - *Inventory of marine animals and plants*: Use the provided Group Chart to combine answers onto one page.
   - *Other additional information*: Use a separate piece of paper to record significant information pertaining to sea level rise and climate change.

NGSS:
Have students write a summary of their findings, as an argument supported by evidence, of how increased human fossil fuel use is impacting climate and ocean conditions in Hawai‘i.

Part 3: Summarizing

9. **Have each group give a short summary and highlight information that students feel the rest of the class can benefit from knowing.**

10. **Refer back to the K-W-L Chart, record new information learned (L) and discuss.**
    - Discussion Questions:

- What changes or unusual events (i.e. prolonged drought, heavy rainfall, etc.) have occurred? How might these be related to climate change over time?
- What significant events (i.e. hurricane, tsunami, water shortage, etc.) have occurred? Are these clues to climate change? Why or why not?
- What changes have occurred in marine plants or animals? How might these changes be related to a changing climate or ocean conditions?
- What kind of impact would the loss of these marine populations have on our community?

EXTENDING THE LEARNING

- In Lesson 5 students will be looking at ways to care for the environment to increase resiliency as a way of mitigating impacts from climate change. One key action is to protect our reefs. To help students discover the impact of sedimentation on reefs, conduct the following experiment, contributed from field test teacher Ululani Victor of Ke Kula ʻo Samuel M. Kamakau Charter School who based this on Joseph Priestly"s famous 1771 experiment:

  Materials: stopwatch, a few sheets of lightly tinted plastic (report covers or smudged sheet protectors work well), several clear jars or plastic bottles, votive candles, bbq lighters or fireplace matches, and small potted plants

  Set-up: It's best to do this in a well-ventilated area or one that doesn't have active smoke detectors. Prepare the jars by leaving one fully clear and then adding additional layers of tinted plastic to each successive jar so that light entering the jar's interior is seriously reduced. Explain to students that this represents the presence of particulate matter in the water column, which is a fancy way of talking about turbidity that is often the result of disturbances to the land resulting in erosion of soil into the ocean.

  Procedure:
  1. Put a small potted plant and an unlit votive candle in each jar. Let the jars sit uncovered for a few minutes in direct sunlight (to allow the air inside the jar to equalize with the outside, and then to build up a decent reservoir of oxygen via photosynthesis).
  2. When everything is ready, get some volunteers to help you; they will be lighting the candles and screwing the lids on the jars as simultaneously as they possibly can.
  3. Once all the candles have been lit, and all the jars have been lidded, start the stopwatch.

4. Press the "lap" button each time a candle goes out. Barring any unforeseen lab error, you should see the darkest jar's candle go out first, and the clear jar's candle go out last.
5. Discuss the implications of these results for the marine environment.
   - Why does the candle stay lit longer in the clear jar? (It gets more sunlight, which means that more photosynthesis is happening, thereby producing more oxygen to keep the candle "on" longer.)

   - The darker jars simulate what happens when sediments cover the reef. Why is sedimentation a problem? (Cloudier water mean less sunlight, less oxygen, and less plant growth. Less plant growth means less food for fish, and, eventually, less fish.)
   - As we anticipate higher sea level in Hawai‘i, why is it important to care for the health of our reefs? (Reefs help to dissipate wave energy and protect our shorelines.)

- Arrange for students to visit the Hawai‘i Institute of Marine Biology to learn more about research related to climate change. Dr. Ku‘ulei Rodgers is working with the Coral Reef Ecology Lab to study corals, including coral bleaching and ocean acidification. The lab sets up mesocosms that simulate what the reef conditions would be in the future with a warmer, more acidic ocean to see how the corals would respond. See a video about her work at: http://www.youtube.com/watch?v=tq4eDqHcEBM

- Have students use the Hawaiian Moon Calendar and track phases with the class. Have them make observations to determine if the calendar is still an accurate tool. Have them write a reflection explaining their observations and whether or not it is a reliable tool. Have students compare pre- and post-Western contact timeframes.

References

Fletcher, Charles H. *Hawai‘i's Changing Climate Briefing Sheet, 2010*. Honolulu: University of Hawai‘i Sea Grant College Program. Center for Island Climate Adaptation and Policy (ICAP). 2010.

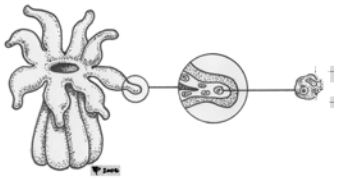
Jokiel, Paul L. and Eric K. Brown. “Global Warming, Regional Trends and Inshore Environmental Conditions Influence Coral Bleaching in Hawai‘i.” *Global Change Biology*. Volume 10, Issue 10. October 2004.

McFadzien, D., F. Areki, T. Biuvakadua, and M. Fiu. *Climate Witness: Community Toolkit*. World Wildlife Fund: Suva, Fiji. 2005.

Student Reading 2
Coral Bleaching

Focus Question: What environmental clues provide evidence for climate change in Hawai'i?

Have you ever been snorkeling and noticed part of the coral is white (looking bleached out)? This "bleaching"is actually the loss of zooxanthellae--the algae that live within the tissues of the coral polyps and produce food for the coral through photosynthesis.



Since corals thrive in a narrow band of warm water temperatures, from about 77° F to 84° F (25° C to 29° C), even a slight rise in ocean temperatures can harm them. This is especially noticeable in El Niño years when ocean temperatures are warmer. El Niño are warm surface currents that occur every three to eight years in the Pacific. If conditions are right in Hawai'i, such as warm temperatures and low winds in bays and lagoons, there can be large-scale bleaching of corals like there was in the late summer of 1996 and again in 2002 (Jokiel 2004). Draw a diagram that shows the cause and effect of what can happen to coral in an El Niño year.

Causes → Effects

- Work with a partner, go to the Reef Check Hawai'i website on coral bleaching and answer the questions below: http://www.reefcheckhawaii.org/eyesofthereefBleach.htm

What is the symbiotic relationship between coral and zooxanthellae?
What is the main climate change indicator for this relationship breaking down?
How would reducing your carbon footprint (the amount of CO_2 released into the atmosphere by your actions) help to protect corals? What is the connection between increased CO_2 and coral bleaching?
What other actions can we take to protect our reefs?

- Ask people in your community if they have observed coral bleaching (when and where) and record this information on Learning Log 5.

LEARNING LOG 5:
COMMUNITY OBSERVATIONS

NAME:_____ **DATE:** _____

Using information from your interview(s), complete the following sections.

Calendar of Seasonal Observations

Record local observations of changing conditions and the month(s) that they occurred for each category. Review the list of climate change indicators for Hawai‘i at the bottom of the page. List possible links between observations and indicators in the last column. Examples have been provided for you.

Community Observations		Timeline (in Months)	Possible Link to Climate Change Indicator
Shoreline	The beach is getting more narrow in winter and trees are falling along the shoreline.	October - April	Rising sea level
Marine Plants and Animals	Hawaiian moon calendar (1922) shows moi leave to spawn from May to September. 2012 observation moi spawning from June to October.	Moi spawning one month later - June to October	
Agriculture			
Weather	There is an increase in mudslides, flash floods and road closures.	October - April	
Human Activities	Our community fish for ‘oama (young weke or goatfish) near the shore in September. We used to fish for them in August.	September	

Climate Change Indicators: increased surface air temperature, declining rainfall and stream discharge, increased rain intensity, increased sea level, increased sea surface temperature, ocean acidification

Timeline of Events

Date	Event
March 11, 2011	Japan had an enormous earthquake that generated a tsunami that struck Hawai‘i.

Which of the events or changes do you believe relate to a climate change indicator?

Explain your thinking. What are the links between the evidence you have gathered and the indicators of climate change in Hawai‘i?

Inventory of Changes Observed in Marine Plants and Animals

Name	Use or Significance	Changes Observed	Location
Coral	Foundation of coral reefs	Coral bleaching (coral heads turned white in some areas)	Kāneʻohe Bay 2002

Other Information

LEARNING LOG 6: INTERVIEW GUIDELINES

NAME: _____ **DATE:** _____

Developing Interview Questions

1. For each category below, write two questions that you could ask your parents, grandparents, kūpuna or community member to learn more about climate change in your area. Refer to **Learning Log 5** to determine the type of information that you need to gather.

   Calendar of Seasonal Observations

   a. _____

   b. _____

   Timeline of Events

   a. _____

   b. _____

   Inventory of Changes Observed in Plants and Animals

   a. _____

   b. _____

2. Get together with 3 to 4 people and write out all your questions on chart paper.
   - Don't add duplicate questions and combine very similar questions.
   - Leave space between questions to edit.

3. Check your group's questions against the rubric below. If you answer "No" to any of these criteria, rewrite the questions that need revision.

Criteria for Good Interview Questions	Yes	No
a. Are your questions open-ended? Do they require more than a "yes" or "no" or other short answer?		
b. Are your questions worded politely and formally? (Does your word choice reflect respect for age and experience and show appreciation?)		
c. Do your questions shed light on: 1. Observations about changes in weather and climate over time? 2. Events that happened in the past regarding changes to the shoreline or ocean conditions? 3. Changes in marine plants and animals over time?		

Preparing for the Interview - *Hō'ihi* (Respect)

The interview is a privilege and should be conducted with respect and appreciation. As a group, write a greeting that:

a. Introduces the topic you are going to be asking questions about
b. Tells why you are going to conduct the interview
c. Asks permission to ask questions and uses the information in your report

The Interview - *Mahalo*

- Everyone should have a copy of all the questions your group developed during the planning process. You may not use all of them; they are to guide your interview. Let the conversation flow naturally and don't be afraid to follow up with other questions on the spot.
- Take a notepad and pen to take notes, or a tape recorder (you must ask permission to record and get their permission recorded on tape).
- Remember to thank your informant after the interview is completed.

Insert your final interview questions below.

Group Chart - Calendar of Seasonal Observations

Community Observations		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Shoreline Environment													
Marine Plants and Animals													
Agriculture													
Weather													
Community Events													

Group Chart - Inventory of Changes in Marine Plants and Animals

Name	Use or Significance	Changes Observed	Location

Which of the above changes might be related to climate change over time? How could we find out more about these changes? Explain your answer.

Satellite "Eyes" on the Earth

How can modern technology help us
to measure and predict sea level changes and impacts?

Activity at a Glance

Students use the Internet to investigate how satellites collect data related to climate change. They examine and compare real-time data for sea level height and temperature, and then investigate sea level trends in Hawai'i. Finally, they explore the "Blue Line Project" and discuss how technology helps scientists to predict future sea level changes.

Key Concepts

- The growth of technology over time provides us with new tools to predict sea level changes due to more gradual sea level rise or natural disasters such as tsunamis.
- Examining data and looking at patterns of association between quantities helps us to understand the potential impacts of sea level rise.

Skills

Creating charts and graphs, collecting and interpreting data, comparing and contrasting, predicting

Assessment

Students:

- Develop graphs and interpret information using real-time data.
- Describe the meaning of symbols on charts and their connection to sea level change.
- Interpret sea level predictions and connect these predictions to the use of technology.
- Draw conclusions about data derived from satellite information.

Suggested Timeframe

Three 45-50-minute class periods

Day 1: Introduce satellites; Learning Log 7

Hawai'i State Standard Benchmarks

Science 1: The Scientific Process - Scientific Inquiry

- **SC.8.1.1** Determine the link(s) between evidence and the conclusion(s) of an investigation.

Science 2: Nature of Science -Science, Technology and Society

- **SC.8.2.1** Describe significant relationships among society, science, and technology and how one impacts the other.

Science 2: Nature of Science - Unifying Concepts and Themes

- **SC.8.2.2** Describe how scale and mathematical models can be used to support and explain scientific data.

Common Core Standards

Math: Functions

- **8.F.4** Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (x,y) values, including reading these from a table or from a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models, and in terms of its graph or a table of values.

Nā Honua Mauli Ola

'Ike Honua: Sense of Place Pathway:

- **NHMO.8.9** Understand the symbiotic relationship between people and their environment.

Day 2: Sea surface temperature and Height; Learning Log 8
Day 3: Sea level trends in Hawai‘i; Learning Log 9

MATERIALS

Provided

- Learning Log 7: Exploring Eyes on the Earth 3D
- Learning Log 8: Sea Surface Temperature and Height
- Learning Log 9: Sea Level Trends in Hawai‘i
- Sea Surface Temperature and Sea Surface Height charts

For You To Provide

- Computers for classroom sessions and student research

GETTING READY

- Prepare your classroom to be sure that your class will have access to the Internet to complete this lesson. Preview the following websites:
  - NASA’s "Ocean Topography from Space" website. See: http://sealevel.jpl.nasa.gov/files/archive/ost/index.html.
  - NASA's Eyes on the Earth 3D website. See: http://eyes.nasa.gov/earth/
  - NOAA's Sea Levels Online website. See: http://tidesandcurrents.noaa.gov/sltrends/sltrends.html
- Print out color copies of the Sea Surface Temperature (SST) Contour Chart and the Sea Surface Height Deviation (SSHD) Chart and Learning Logs 7 - 9 for students.

VOCABULARY

Satellite altimetry: a technique for measuring sea surface height using radar instruments traveling on orbiting satellites

Sea surface height deviation (SSHD): the height of the sea surface above or below some reference point

Sea surface temperature (SST): the temperature of the ocean's surface water

TEACHER BACKGROUND INFORMATION

Have you ever looked up to the night sky and seen a bright light soaring across the sky? Chances are that it was not a shooting star, but a satellite collecting valuable information about our planet. NASA currently has over a dozen satellites constantly circling the Earth, monitoring our land, atmosphere, and oceans. Data collected from these satellites provide scientists with critical information and allows them to monitor the “vital signs” of the Earth. Signs such as sea level height, concentration of carbon dioxide within our atmosphere, global temperatures, and the extent of sea ice in the Arctic are among the data collected. Together, these data help paint a picture for scientists and others to determine what is happening to the Earth’s climate and to predict how it will change in the future.

NASA’s “Eyes on the Earth 3D” website uses state-of-the-art technology to display the location of over a dozen of NASA's Earth-observing missions that are currently in orbit. This world-class technology allows users to explore missions in different capacities as well as display real-time locations of missions. Users are able to ride side-by-side with a spacecraft, observe Earth as it sweeps below in accelerated time, view data maps of sea level or carbon dioxide distribution, compare the size of each satellite to a car or a scientist, and even see the changes of Earth’s sea levels in 3D. Informative videos and animations are also available to enhance the learning

experience. It's an incredible resource for educators and promises to captivate and intrigue students (NASA/Jet Propulsion Laboratory 2009).

Investigating Sea Surface Temperature and Height Using Technology
Scientists have gathered sea surface temperature and height data for more than three decades that provides evidence of a direct correlation between the two. As sea surface temperatures increase, water expands forcing sea surface height to increase. The ocean's surface typography is comprised of various high and low points. This variation is influenced by different factors such as wind which can account for up to two meters of sea level variation. Another factor that can affect sea surface typography is the Pacific Dacadal Oscillation which has warming and cooling phases lasting 10 to 30 years. Sea level is very dynamic and complex. Satellite altimetry has made it possible to record and visualize this data.

NASA's "Ocean Surface Topography from Space" website in an interactive site that easily explains different facets of ocean surface topography. It provides in-depth information about altimetry, sea surface temperature, sea surface height, as well as other natural ocean phenomena such as El Niño and El Niña. The site also shows the big picture in relation to oceans and climate and predicting climate. This website is extremely helpful for students to understand how satellites play a significant role in gathering important data (NASA/Jet Propulsion Laboratory 2011).

Exploring data in real-time brings the most current information to users. With today's technology, sea surface temperature and sea surface height information is readily available in a nearly real-time format. Contour charts displaying these two types of data can be compared and graphed.

Sea Level Trends
For over 150 years, NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) program has been measuring sea level. It utilizes data obtained from 128 tide stations located along all U.S. coastlines. Changes in the mean sea level at each station have been recorded when sea level rises or falls. These recordings have been documented for a minimum of 30 years at each station. Once the information is recorded at each station, measurements are averaged by month to get an accurate reading. This avoids irregular data caused by unusually high waves, tides, and tsunamis. The result is a sea level trend.

NOAA's Sea Levels Online website provides a world map of sea level trend data. Sea level trend heights are color-coded in millimeters per year. The magnitude of change is indicated by the height of arrows, and the arrow's direction indicates whether the trend is rising or falling. Because this website takes advantage of high quality satellite imagery, locations can be zoomed in to see details. Clues about change may be evident in the map where some areas are experiencing rapidly rising levels while other areas may have decreasing levels (NOAA 2011).

Sea level at any one place can change for two principle reasons: (1) If more water enters the ocean through precipitation and run-off than leaves through evaporation and/or the water in the ocean expands through heating, then sea level will rise globally. This is known as a "eustatic"

change in sea level. (2) The local area can sink tectonically for any of several reasons, such as withdrawal of groundwater or additional weight added to the area through volcanism. If the ground sinks, then sea level will be seen to rise. But this is a "local" rise in sea level and only occurs in those areas that are sinking.

A good example of this is the difference in sea level rise measured in Honolulu and Hilo. According to the Hawaiian Volcanoes Observatory, sea level rose about 8 in (20.3 cm) in Hilo during the last half of the 20th century. During the same period, sea level rose only about 3.5 inches in Honolulu. The difference is the 4.5 in (~ 9 cm) that Hilo sank relative to Honolulu over that 50-year period. The reason for this difference lies in the great weight of the islands that slowly bends the underlying lithosphere. As the volcanoes grow, their weight is greater than the lithosphere can support. The result is that the lithosphere flexes downward under the increasing weight of the growing island. The downward flexing is a response to increases in the weight of the island, and is most rapid while the island is rapidly growing. The older Hawaiian Islands, such as O'ahu and Kaua'i, have already completed their period of rapid growth and rapid subsidence. Their much slower subsidence rates result in much smaller changes in relative sea level, whereas Maui and Hawai'i Island are still growing and sinking more rapidly, hence they have more rapidly rising sea level.

The Blue Line Project

Dr. Charles Fletcher, a marine geologist at the University of Hawai'i at Mānoa, recommends that local decision-makers begin planning adaptations to rising sea levels by targeting a sea level increase of 1 ft (0.30 m) by mid-century, and about 3.3 ft (1 m) by the end of the century (Fletcher, 2008). Such a sea level rise will cause many low-lying shoreline areas to be flooded by the end of the century. Dr. Fletcher has worked with his team to create aerial maps that show the impact of a one meter increase in sea level along the coast of Waikīkī and other parts of the state.

This one-meter sea level rise is referred to as the "blue line." Fletcher and his team used sensitive topographic data to map a blue contour line marking areas that are 1 meter above today's high tides. The dramatic result demonstrates the potential impact that global climate change will have on island communities. For example, seawater will inundate much farther inland during high waves, storms and tsunamis; low-lying storm drains will flood with seawater during changes in the tides, and many landmarks will be flooded and lost.

Dr. Fletcher's Sea Level Rise website provides animation of the blue line for areas of O'ahu, Maui and Kaua'i. It also includes video and images of local flooding and areas that can be impacted by future sea level rise. Informative PowerPoint presentations by Dr. Fletcher offer greater detail about climate change and sea level rise in Hawai'i. This tool will create interest and awareness about sea level change. The fly-overs from a bird's eye view of the blue line are an excellent tool for students (Fletcher 2008).

TEACHING SUGGESTIONS

Part 1: Introducing Satellites

1. **Introduce the focus question for the lesson and have a brief discussion with the class.**
   Focus Question: *How can modern technology help us to measure and predict sea level changes and impacts?*
   Possible discussion questions:
   - What kind of technology do we have available to measure sea level changes?
   - How do you think satellites help us measure sea level changes?
   - What types of data do you think satellites collect?
   - Can information gathered from technology be helpful in understanding climate impacts in our world?

NGSS:
Have students ask questions about the data collected by satellites to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

2. **Introduce groups to NASA's Eyes on the Earth 3D website. See: http://eyes.nasa.gov/earth/**
   - Divide the class into groups of two to three students.
   - Point out that the satellites are circling the Earth, monitoring different vital signs.
   - Distribute **Learning Log 7** to each student and ask them to use the information on the website to answer the questions.

3. **Reinforce earlier discussions by reviewing the information that can be gathered using satellites.**
   - Introduce groups to NASA's "Ocean Topography from Space" website. See: http://sealevel.jpl.nasa.gov/files/archive/ost/index.html.
   - Under the "Science and Instruments" tab, have students explore the "Altimetry," "Sea Surface Height," and "Sea Surface Temperature" tabs. Scroll over the white text to point out different key topics.

NGSS:
Analyze and interpret satellite data to forecast future sea surface temperature and sea level rise based on current trends. Discuss technology to mitigate the effects.

Part 2: Sea Surface Temperature and Height

4. **Distribute Learning Log 8 to each student and the Sea Surface Temperature and Sea Surface Height charts**
   - Have each group complete **Learning Log 8.**
   - Discuss their responses to the Learning Log.

5. **Have students investigate future sea level predictions using technology by having them explore sea level trends found at NOAA's Sea Levels Online website. See: http://tidesandcurrents.noaa.gov/sltrends/sltrends.html.**
   - Have each group examine the world map with sea level trend arrows and have a discussion about what the arrows mean.
     - What do different colors represent?
     - What is the significance of the height of the arrow?
     - What places in the world are experiencing sea level rise and fall?
     - Why do you think this is happening?

Part 3: Sea Level Trends in Hawai'i

6. **Have students investigate sea level trends in Hawai'i using the sea level trends website above.**
   - Ask students to use the information to answer **Learning Log 9.**

7. **Review the Blue Line Project website (http://www.soest.hawaii.edu/coasts/sealevel/) with the students by exploring videos of locations near your school.**
   - After reviewing the "Blue Line Project", instruct students to write a brief reflection explaining the link between scientific evidence and the conclusion that sea level is rising in Hawai'i.

EXTENDING THE LEARNING

- Have students choose one of NASA's many missions and do an in-depth study about the satellite, the data it collects, the methods of collection, etc. and have them create a report or display about the mission.

- Explore the main source locations for carbon dioxide on our planet and play the "Metropolis" game found on NASA's Eyes on Earth 3D website.

References

Cook, John. "Predicting Future Sea Level Rise." *Skeptical Science*, December 18, 2009. Accessed November 5, 2011. *http://www.skepticalscience.com/Predicting-future-sea-level-rise.html*.

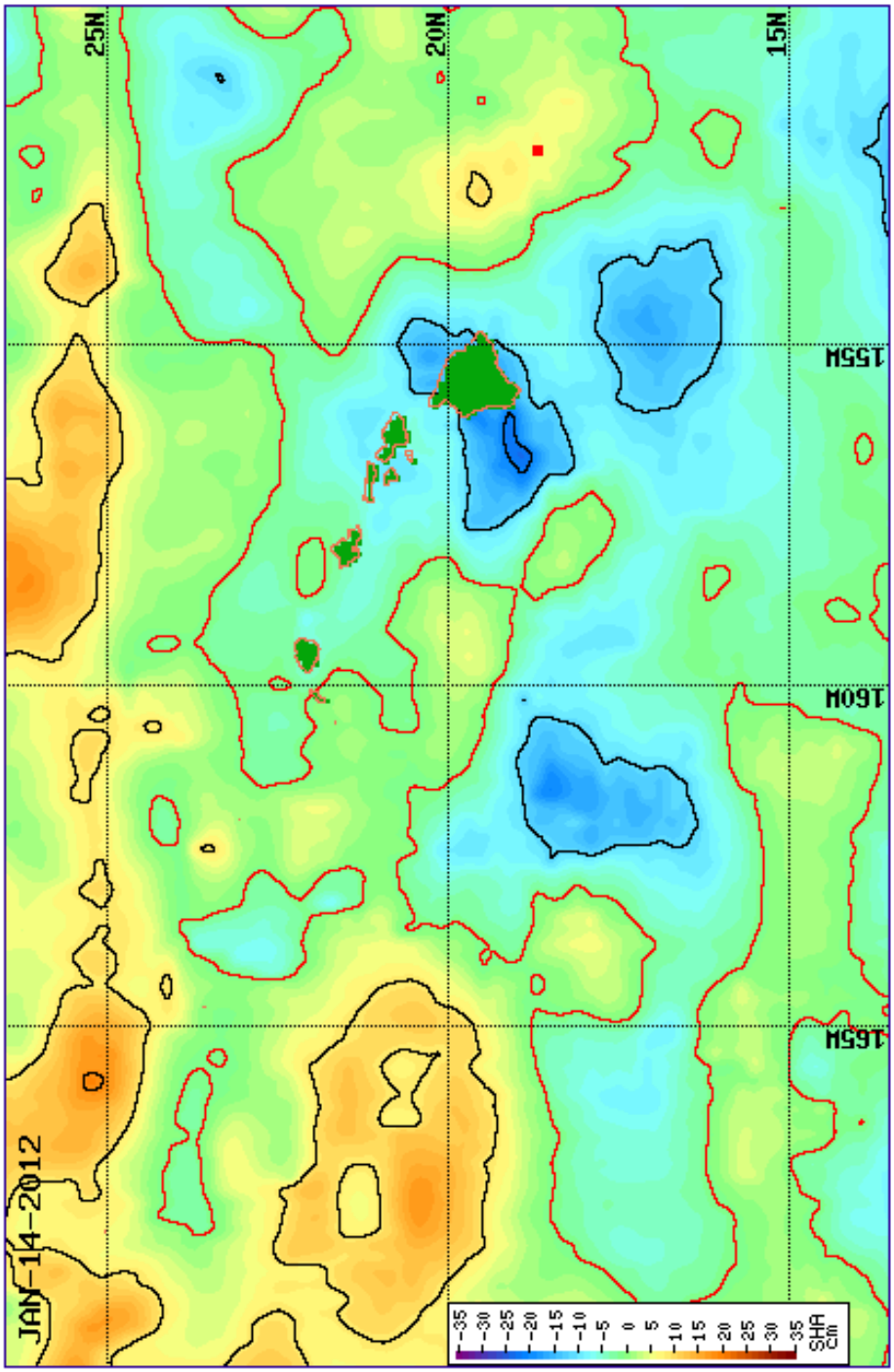
Fletcher, Chip. "Sea Level Rise Website: Hawaii's Changing Climate." 2008. Accessed June 7, 2013. http://www.soest.hawaii.edu/coasts/sealevel/

National Aeronautics and Space Administration (NASA). “New Vision for 'Eyes on the Earth'.” *Global Climate Change: Vital Signs of the Planet*. Accessed November 2, 2011. http://climate.nasa.gov/news/index.cfm?FuseAction=ShowNews&NewsID=145.

National Aeronautics and Space Administration (NASA). “Ocean Surface Topography from Space.” 2011. Accessed November 2, 2011. http://sealevel.jpl.nasa.gov/files/archive/ost/index.html.

National Oceanic and Atmospheric Association (NOAA). "Sea Levels Online.” *Tides and Currents*. 2011. Accessed November 6, 2011. http://tidesandcurrents.noaa.gov/sltrends/sltrends.html

Sea Surface Height Chart

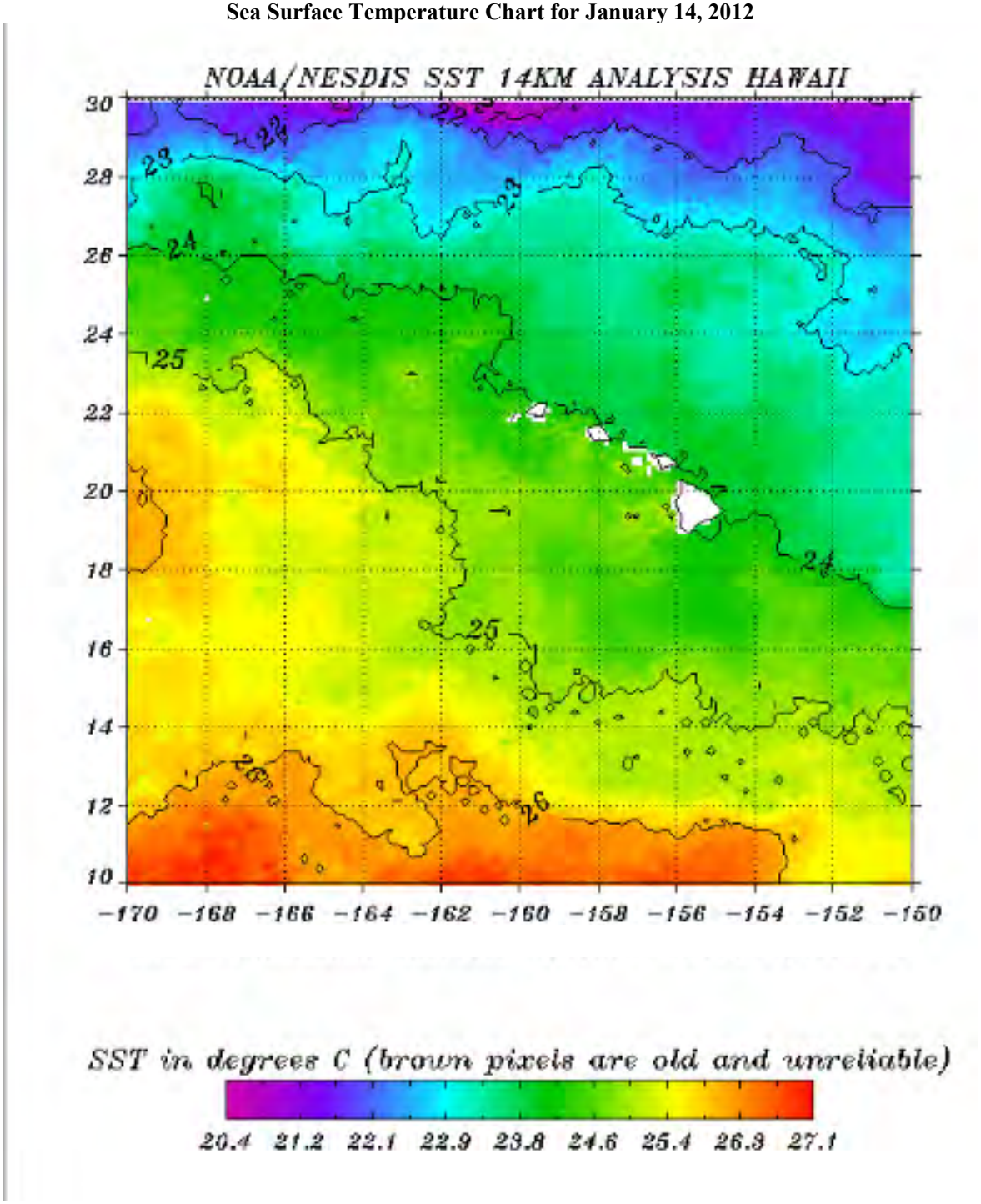


Sea Surface Height Chart for January 14, 2012.

Key: SHA = Sea Height Anomaly: Measured as the difference between the best estimate of the satellite-observed sea surface height and a mean sea surface.

Sea Surface Temperature Chart

Sea Surface Temperature Chart for January 14, 2012



http://www.osdpd.noaa.gov/ml/ocean/sst/contourthumb.html

Learning Log 7: Exploring Eyes on the Earth 3-D

Name_____ **Date**_____

1. NASA has summarized different vital signs of Earth. Record each vital sign's measurement in the table below.

Vital Sign	Measurement
Arctic Sea Ice Minimum	
Carbon Dioxide	
Sea Level	
Global Temperature	
Ozone Hole	

Using NASA's Eyes on the Earth 3D website: http://eyes.nasa.gov/earth/ to answer the following questions:

2. Click on the "Missions" button at the top of the screen (the last in the group of icons). You will see NASA's missions grouped into three different categories: atmosphere, sea, and land. For each category below, choose a NASA mission and write the name of the mission, its purpose, and place a check in the box for the vital sign that mission addresses. An example has been provided for you.

Mission Name	Purpose	Vital Signs				
		Arctic Sea Ice Minimum	Carbon Dioxide	Sea Level	Global Temperature	Ozone Hole
Atmosphere						
CLOUDSAT	Studies the internal structure of clouds				X	
Sea						
Land						

3. Click on the OSTM mission and view the vital sign in the sea level data. Use the map to answer the following questions: (Note: you may need to zoom in and out to view data in detail and be sure to view the globe in 3D to see the changes in height along the edges of the Earth.)

What is this map an example of?_____

The map's colors indicate different temperatures and sea levels. Make a prediction about the waters surrounding Hawai‘i and complete the following statement.

If the water's color is _____ then the water's temperature is _____ which

means that sea level is _____.

Choose another site on Earth that has a color different than Hawai‘i. List the

site:_____

If the water's color is _____ then the water's temperature is _____ which

means that sea level is _____.

Check to see if your predictions above were correct. Does everything look as you expected? Explain.

LEARNING LOG 8: SEA SURFACE TEMPERATURE AND HEIGHT

NAME_____ **DATE**_____

NASA's "Ocean Topography from Space" website has interactive information about Sea Surface Temperature (SST) and Sea Surface Height (SSH). Use this website to define the following words:

Altimetry:

Sea surface temperature:

What two reference surfaces are used to determine sea surface height? Define these words.

Using the "altimetry" page under the Science and Instruments tab, http://sealevel.jpl.nasa.gov/files/archive/ost/index.html, fill in the following information about satellites:

1. Located _____ above Earth, TOPEX/Poseidon and Jason measure _____ directly below the satellite with an accuracy of _____. Traveling nearly _____ the satellite maps the global oceans every _____.
2. How many rotations around the Earth does the satellite make in 10 days? _____
3. If the satellite makes two rotations around the Earth every 20 days, write an equation that shows the relationship between the number of days (x) and the number of rotations (y). Write your equation with y first followed by an equals sign.

4. How many days will it take for the satellite to map the global oceans after three rotations? _____
5. If the satellite travels 15,000 mph for five days, what proportion of the Earth's oceans have been mapped? _____

Take a look at the Sea Surface Temperature and Sea Surface Height charts that your teacher has provided you.
What dates do the maps represent? _____

Using the color information along the 21 N degree axis, record the sea surface temperature (SST) and sea surface height (SSH). (Hint: Draw a line along the 21 N degree axis.)

Longitude (°W)	-168	-166	-164	-162	-160	-158	-156	-154	-152	-150
SST (°C)										
SSH (cm)										

Using graph paper, use your data table above to create two graphs: 1) sea surface temperature and 2) sea surface height, over the distance of the ocean. Be sure to label the X and Y axes appropriately.

Do your graphs look similar? What can you can conclude from these graphs? Explain.

LEARNING LOG 9: SEA LEVEL TRENDS IN HAWAI'I

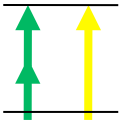
NAME_____ **DATE**_____

Use NOAA's "Sea Levels Online" website to investigate information about sea levels in Hawai'i.

1. On the world map page (http://tidesandcurrents.noaa.gov/sltrends/sltrends.html), zoom in to the Hawaiian Islands. Examine the arrows. Are all the arrows the same color and height? Explain what they mean.

   a. If  is equal to 3 mm/yr, then  is equal to _____ mm/year.

   b. Write the equation for this problem. _____

   c. Write an equation that represents the length of the yellow line. 

2. Click on an arrow closest to your school.

   a. What is the name of the location: _____

   b. What was the color key's range of sea level trend for the color of the arrow?

      _____

   c. Is sea level rising or falling? _____

   d. What is the mean sea level trend? _____

   e. In 100 years, what is the predicted measurement of change (ft/century) in sea level at this location? _____

f. Is sea level changing the same throughout the state? Why or why not?

3. Zoom back out to the world map. Find at least three other locations where sea level is drastically changing and note the information below.

Location	Is sea level increasing or decreasing?	Mean Sea Level Trend	100 Year Change

Do these locations have any similarities in climate?

Learning Log 7: Exploring Eyes on the Earth 3D (Answer Sheet)

Name_____ **Date**_____

1. NASA has summarized different vital signs of Earth. Record each vital sign's measurement in the table below.

Vital Sign	Measurement
Arctic Sea Ice Minimum	Decreased 11.5% per decade
Carbon Dioxide	Increased to 391 parts per million
Sea Level	Increased 3.27 mm since 1992
Global Temperature	Increased 1.5°F average temperature since 1880
Ozone Hole	10.4 million square miles

Using NASA's Eyes on the Earth 3D website: http://eyes.nasa.gov/earth/ to answer the following questions.

2. Click on the "Missions" button at the top of the screen (the last in the group of icons). You will see NASA's missions grouped into three different categories: atmosphere, sea, and land. For each category below, choose a NASA mission and write the name of the mission, its purpose, and place a check in the box for the vital sign that mission addresses. An example has been provided for you.

Mission Name	Purpose	Vital Signs				
		Arctic Sea Ice Minimum	Carbon Dioxide	Sea Level	Global Temperature	Ozone Hole
Atmosphere						
CLOUDSAT	Studies the internal structure of clouds				X	
ACRIMSAT	Studies the Sun's energy output				X	
AQUA	Studies weather and climate					
AURA	Monitors the health of the Earth's atmosphere					X
CALIPSO	Observations of clouds and aerosols				X	
QUICKSCAT	Measures wind speeds				X	
SOURCE	Measures the sun's radiation				X	
TRIMM	Monitors tropical and sub-tropical rainfall				X	
Sea						
JASON1	Measures sea level from space			X		
OSTM	Measures sea level from space			X		

Land						
EO1	Advanced land-imaging mission	X				
GRACE	Measures Earth's gravity field	X				
LANDSAT7	Images the Earth's surface	X				
TERRA	Earth Observing System flagship				X	

3. Click on the OSTM mission and view the vital sign in the sea level data. Use the map to answer the following questions: (Note: you may need to zoom in and out to view data in detail and be sure to view the globe in 3D to see the changes in height along the edges of the Earth.)

What is this map an example of? Average sea level variation over a one-month period

The map's colors indicate different temperatures and sea levels. Make a prediction about the waters surrounding Hawai‘i and complete the following statement.

If the water's color is blue then the water's temperature is cool which means that sea level is low.

Or if the water color is red then the water temperature is hot, which means that sea level is high.

Choose another site on Earth that has a color different from Hawai‘i.

List the site:_____

If the water's color is _____ then the water's temperature is _____ which

means that sea level is _____.

Check to see if your predictions above were correct. Does everything look as you expected? Explain.
If students see a blue color around Hawai‘i, then the water will have a dip in it because it is indicating a lower sea level compared to surrounding areas and vice versa if the color is red. (Hint: To see this image, students should use the slowest speed, angle Earth in a position where its profile can be easily seen, and zoom in on the area.)

Learning Log 8: Investigating Sea Surface Temperature and Height (Answer Sheet)

Name_____ **Date**_____

NASA's "Ocean Topography from Space" website has interactive information about Sea Surface Temperature (SST) and Sea Surface Height (SSH). Use this website to define the following words:

Altimetry: The determination of the height of an object with respect to a reference such as sea level.

Sea Surface Temperature: The temperature of our ocean's uppermost waters.

What two reference surfaces are used to determine Sea Surface Height? Geoid and ellipsoid. Define these words.

Geoid: The shape of a sea surface of an ocean at rest.

Ellipsoid: A reference surface that approximates Earth's shape.

Using the "altimetry" page under the Science and Instruments tab, http://sealevel.jpl.nasa.gov/files/archive/ost/index.html, fill in the following information about satellites:

1. *Located 1336 km (830 mi) above Earth, TOPEX/Poseidon and Jason measure sea surface height directly below the satellite with an accuracy of about 3 cm (1.2 in). Traveling nearly 7 km/sec (over 15,000 mph) the satellite maps the global oceans every 10 days.*

2. How many rotations around the Earth does the satellite make in 10 days? 1

3. If the satellite makes two rotations around the Earth every 20 days, write an equation that shows the relationship between the number of days (x) and the number of rotations (y). Write your equation with y first followed by an equals sign. y = x/10

4. How many days will it take for the satellite to map the global oceans after three rotations? 30 (Question #4 uses the equation created in Question #3. So the student should plug in 3=y and find x, which equals to 30.)

5. If the satellite travels 15,000 mph for five days, what proportion of the Earth's oceans have been mapped? 1/2 (Question #5's answer is dependent upon info in Question #1. Since it takes 10 days to make one full rotation around the Earth, traveling at a speed of 15,000 mph, in 5 days (as asked in Q4), then half of the oceans should be mapped by this point in time.)

Take a look at the Sea Surface Temperature and Sea Surface Height charts that your teacher has provided you.

What dates do the maps represent? (Date located below SST chart.)
Using the color information along the 21 N degree axis, record the sea surface temperature and sea surface height. (Hint: Draw a line along the 21 N degree axis.)

Longitude (°W)	-168	-166	-164	-162	-160	-158	-156	-154	-152	-150
SST (°C)										
SSH (cm)										

Using graph paper, use your data table above to create two graphs: 1) sea surface temperature and 2) sea surface height, over the distance of the ocean. Be sure to label the X and Y axes appropriately.

Do your graphs look similar? What can you can conclude from these graphs? Explain.

Learning Log 9: Sea Level Trends in Hawai‘i (Answer Sheet)

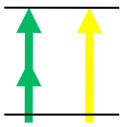
Name_____ **Date**_____

Use NOAA’s “Sea Levels Online” website to investigate information about sea levels in Hawai‘i.

1. On the world map page (http://tidesandcurrents.noaa.gov/sltrends/sltrends.html), zoom in to the Hawaiian Islands. Examine the arrows. Are all the arrows the same color and height? Explain what they mean.
   Students should determine that:
   - The arrows are pointing up, indicating an increase in sea level rise.
   - Most arrows are green indicating a rise of 0 to 3 mm/year and one arrow is yellow with a rise of 3 to 6 mm/year.
   - The length of the arrow relates to the magnitude of change.

   a. If  is equal to 3 mm/yr, then  is equal to _____ mm/year.

   b. Write the equation for this problem. _____

   c. Write an equation that represents the length of the yellow line. 

2. Click on an arrow closest to your school.

   a. What is the name of the location: _____

   b. What was the color key’s range of sea level trend for the color of the arrow?

   _____

   c. Is sea level rising or falling? _____

   d. What is the mean sea level trend? (Click on the arrow to see trend information.)

   e. In 100 years, what is the predicted measurement of change (ft/century) in sea level at this location? (Data listed in last sentence of trend information.)

   f. Is sea level changing the same throughout the state? Why or why not? (Refer to the Teacher Background section for a full explanation.)

Taking Community Action

How do clues from our past and tools of the present help us prepare for future sea level rise?

Activity at a Glance

Student groups determine ways to address problems related to climate change and rising seas. Individually, they create an illustration and write a narrative to describe how sea level change will impact their lives and what they would like their future to look like as we plan for climate-resilient island communities. They reconvene in groups to assess community adaptation and mitigation to address rising sea level and present an action plan to the community during a final hō'ike (exhibit).

Key Concepts

- New technology tools enable us to predict tsunamis and gradual sea level rise over time.
- Geological evidence from the past, current data, and interviews with kūpuna and others provide clues to sea level changes in Hawai'i.
- Sea level rise impacts shorelines, beaches, marine life, structures, and our quality of life on islands.
- Given the predictions for future sea level rise, we can take action today to plan for the future and protect our shorelines and beaches.

Skills

Problem-solving, analyzing, diagramming, collaborating, communicating orally, writing

Assessment

Students:

- Collaborate in teams to develop a community action plan to address problems related to sea level rise.
- Report on their findings using posters or computer presentations or other media.
- Write a paper to summarize links between climate change evidence and future sea level rise predictions, to describe how sea level rise will affect their lives, and to envision how the community should adapt to sea level rise in the future.

Hawai'i State Standard Benchmarks

Science 1: The Scientific Process -Scientific Inquiry

- **SC.8.1.1** determine the link(s) between evidence and the conclusion(s) of an investigation.

Science 2: Nature of Science - Science, Technology and Society

- **SC.8.2.1** Describe significant relationships among society, science, and technology and how one impacts the other.

Common Core Standards

Language Arts: Writing - Production and Distribution of Writing

- **W.8.6** Use technology including the Internet, to produce and publish writing and present the relationships between information and ideas efficiently as well as to interact and collaborate with others.

Language Arts: Writing - Text Types and Purposes

- **W.8.3** Write narratives to develop real or imagined experiences or events using effective techniques, relevant descriptive details, and well-structured event sequences.

Language Arts: Speaking and Listening -Presentation of Knowledge and Ideas

- **SL.8.4** Present claims and findings, emphasizing salient

Suggested Timeframe

Four 45-50-minute class periods plus hō‘ike (exhibit)

Day 1: Review final project criteria
Day 2: Problem solving; Learning Log 10
Day 3: Develop action plans; Learning Log 11
Day 4: Prepare for hō‘ike; conduct unit post-assessment and student self assessment

points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

- **SL.8.5** Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.

Materials

Provided

- Student Assessment Overview and Unit Pre/Post-assessment (provided in Unit Introduction)
- Learning Log 10: Root Cause Analysis
- Learning Log 11: Sun Ray Exercise
- Task Cards
- Self-Assessment Rubric
- Culminating Project Rubrics (provided in Unit Introduction)
- “Climate Change and Pacific Islands” (provided in Appendix)

For You To Provide

- Chart paper
- Post-its

Getting Ready

- ✓ Copy the Learning Logs and Self Assessment Rubric for each student.
- ✓ Copy or prepare to project the culminating project rubrics to review them with students.
- ✓ Copy and out out the Task Cards (one set of 6 for each group of 4 - 5 students).
- ✓ Copy the Unit Pre/Post-assessment for each student.
- ✓ Prepare to project some of the pages from the “Climate Change and Pacific Islands” booklet that is provided in the Appendix.

Vocabulary

Adaptation: in this context, the act of adjusting to a problem
Mitigation: the action of reducing the effects of a problem
Resiliency: the ability to recover from a problem or situation

Teacher Background Information

Although island communities contribute a small portion to the overall problems of global climate change and sea level rise, island communities are among the most vulnerable to their effects. In order for us to understand the impacts of these complex problems and ways to adapt to change, it is helpful to conduct a step-by-step process in which these ideas can be broken down into manageable and understandable bits of information.

WWF South Pacific's Climate Change Team created the *Climate Witness Community Toolkit* to assist island communities in documenting climate change on a local level and to devise meaningful ways for island communities to adapt. The methodologies and processes used in the South Pacific have been useful in helping these island communities in creating community action plans that address climate change. This toolkit has been adapted to focus on this unit's subject--sea level rise (McFadzien, et al. 2005). Some of the methods have already been integrated into previous lessons.

In 2010, Micronesian communities worked together to create a plan for community-based climate change adaptation. They identified what a healthy Micronesian community and atoll should look like and compared them to those that were vulnerable to multiple threats. After reviewing the basics of climate change, the plan takes a good hard look at how climate change will impact their island communities and the potential devastation that could occur. It then looks toward a more positive future and focuses on adaptation strategies to build resilience. It emphasizes the need to keep the land and ocean as healthy as possible and persuades islanders to project positive behaviors. The end result is a well-designed community action plan that was made into several different formats, a flipchart and booklet, in which low-tech islanders can still spread the word about climate change with other Micronesian communities (Gombos, et al. 2010). A copy of this booklet is provided in the Appendix.

This culminating activity focuses on the creation of a Community Action Plan for sea level rise in our communities. There are many factors to consider as we think about building a climate-resilient community. Resiliency can be viewed as a combination of adaptation and mitigation. Following are some points for students to consider as they work on their action plans:

Adaptation - How do we adapt to:

- Increased flooding in coastal areas - impact on roads, buildings, landmarks, cultural sites
- Ocean acidification
- Increased storm intensity

Mitigation: How do we plan future development that:

- Draws less groundwater from our freshwater lens
- Uses land wisely in eroding shoreline areas
- Reduces our dependence on fossil fuels
- Utilizes green energy sources that are most feasible for our island
- Decreases run-off of fertilizers and sediments on our coral reefs
- Creates protected areas for reef organisms
- Updates tsunami inundation zones and evacuation routes

As students go through the process for creating this plan, they are exposed to creative ways of solving problems and discovering solutions. They identify problems, causes and effects, and create tables and diagrams. In the end, they uncover the root of the problem and will present their creative ways of solving problems associated with sea level rise in Hawai'i.

TEACHING SUGGESTIONS

Part 1: Culminating Projects

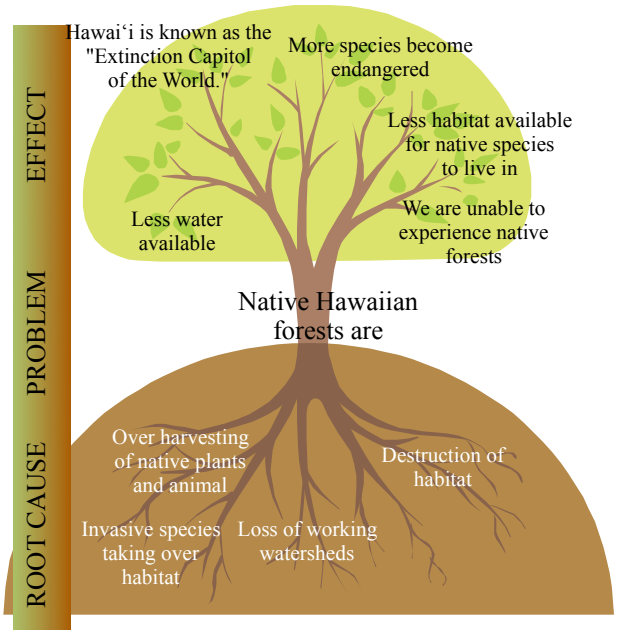
1. **Review the Student Assessment Overview and discuss the students' culminating project that addresses the unit essential question:**
   How do clues from our past and tools of the present help us prepare for future sea level rise?
   - Ask students to generate some initial responses to the essential question.
   - Review the Group Project and Individual Project tasks in the Student Assessment Overview (provided in Unit Introduction). Explain that students will work in groups to create a community action plan that addresses sea level rise in their community.
     - Working in groups, students will present their plans to the entire class and community members during a hō'ike (exhibit).
     - Individually, each student will create a drawing and write a paper to illustrate how sea level rise will impact their lives and what they would like their future to look like as the community adapts to rising sea level.
   - Project or distribute the **rubrics** for the culminating projects and review them with the class to guide students in developing high-quality work.

2. **Review what students have learned in previous lessons.**
   - Discussion Questions
     - Why should we care about global climate change and the effect on sea level?
     - What are some lessons that we have learned from our environment and people that help us understand sea level rise?
     - How has technology improved our way of monitoring sea level rise?
     - What are our concerns and opportunities when it comes to sea level rise?
     - How do we become more responsible citizens to lessen our contribution to global climate change?

Part 2: Problem-Solving

3. **Assist students in determining community problems related to sea level rise.**

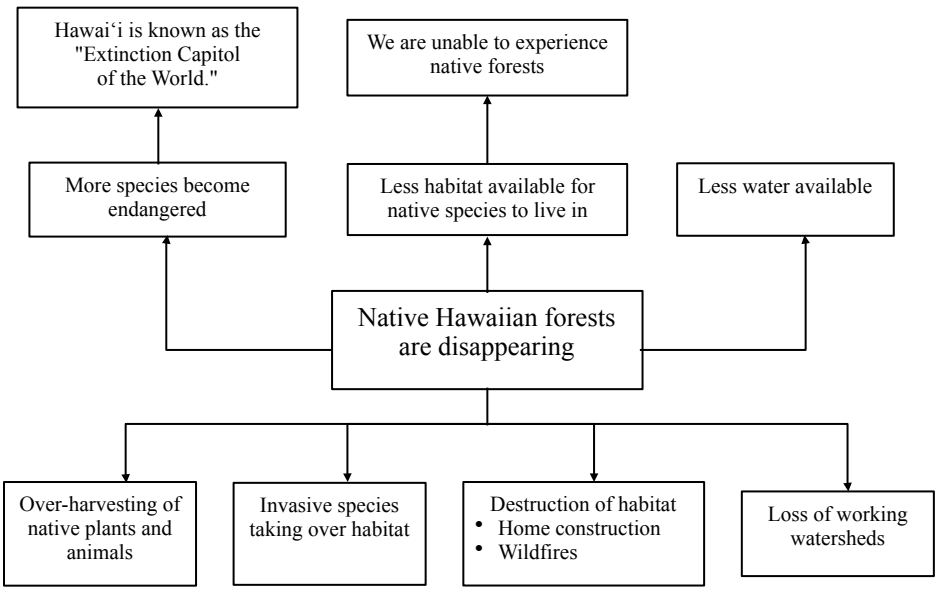
- Project some of the pages from the "Climate Change and Pacific Islands" booklet (see Appendix). Discuss problems that island communities are facing due to rising sea level and make connections to problems in your community.
- Remind students to think about information collected in previous lessons that identify clues from the past and tools of the present.



- Divide the class into groups of four to five students to work together for the remainder of the culminating activity.
- Have each group generate a list of problems facing their community in regard to sea level rise and prioritize them.

4. Lead students through a root-cause analysis of one of the problems.

- Define the terms *problem*, *cause* and *effect* for the students by using the following root cause analysis. An example is provided.
  - Draw a tree with a trunk, leaves and roots.
  - Explain that the tree is sick and is suffering from a problem. Write the problem in the trunk. Explain that in order to understand why the tree is sick, the class must follow the problem back to its roots.
  - Have students brainstorm reasons why the tree is sick. Continue to ask the question, "why?" and label these causes in each root. If there are secondary causes, add them as secondary roots. Continue this process until all possible causes are exhausted.
  - Next, have the students identify what the effect will be. Write primary effects in the branches and secondary effects along smaller branches. Continue this until all possible effects are exhausted.
  - Finally, take the information from the tree diagram and create a flow chart that shows the relationship between the information. The chart below is an example.



5. Have students go through this process with the problems they identified.

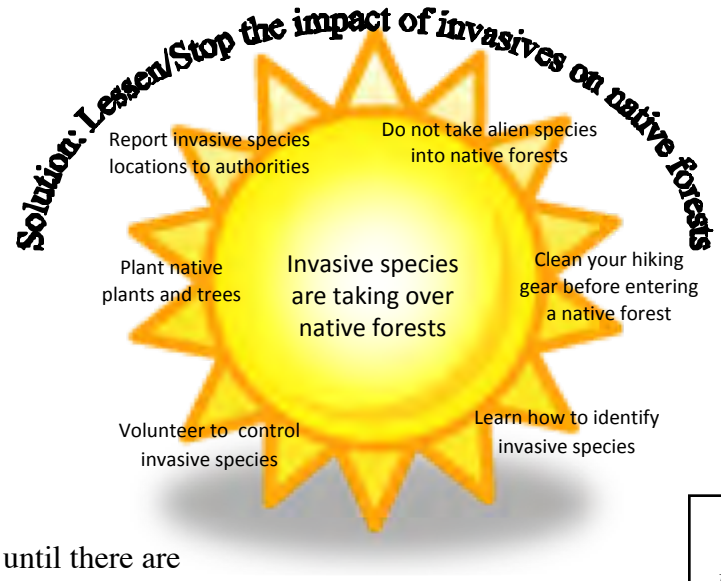
- Have each group take the top four or five problems that they identified related to future sea level rise and go through the root cause analysis for each problem on a sheet of paper.
- Give each group a piece of chart paper and a stack of Post-its.
- Allow the students time to draw a tree on the paper, write their answers on the Post-its, and place them on the tree.
- Once one problem is completed, have them record their findings on **Learning Log 10**. Continue this process until the top four or five problems have been completed. Is sea level rise a root cause of the problem? What would the tree look like if we did a root cause analysis for sea level rise?

Part 3: Developing an Action Plan

6. Assist students in determining what type of actions need to be taken by their community to address climate change and sea level rise.

- Introduce the vocabulary for the lesson and discuss the difference between adaptation and mitigation. Distinguish between reactive (adaptation) and proactive (mitigation) responses and the need for both actions in addressing climate change and rising sea level.
- Lead students in a brainstorming exercise to address ways we can adapt to climate change indicators and how we can work to reduce some of the effects by taking action today.
- Challenge student groups to develop solutions that involve adaptation and mitigation and figure out ways to achieve these solutions.

- Use the following sun ray exercise to help students determine some solutions:
  - Draw the outline of a sun and sun rays on the board.
  - Select one of the root causes of the problem and write it in the center of the sun.
  - Ask the students to identify solutions to the problem. As they respond, write these solutions at the end of the rays.
  - Ask the students to identify ways to achieve each solution. As they respond, write these methods within each ray.
  - Continue to fill the sun's image until there are no more responses.



- Review what has been recorded and assist the students in consolidating methods and solutions if necessary. Discuss the idea that in order for a problem to be solved, certain things need to be achieved or addressed before reaching the solution.

NGSS:

Have students design solutions for adapting to and mitigating damage from sea level rise due to climate change and compare and evaluate group designs for effectiveness.

7. Instruct students to work in their groups and do this exercise with each of the problems that they prioritized earlier.

- Give each group a piece of chart paper and a stack of Post-its.
- Allow the students to address each problem, one at a time, and write their answers on the Post-its then place them on the sun.
- Are the solutions achievable? Do the methods need to be broken down into smaller steps?

8. Have students complete Learning Log 11.

- After assessing each problem, have them transfer their information from the sun ray exercise to the Learning Log.
- Allow them time to discuss and rate the effectiveness of each action according to the scale.
  - Is the action appropriate?
  - Is it something that can be realistically achieved?

NGSS:

Challenge students to develop a method for monitoring one of the climate change indicators in their community.

- Have them decide on the final actions that their groups feel are achievable and rank them from highest to lowest priority.

9. Ask students to create illustrations about their vision of Hawai‘i as a homework assignment.

- Ask students to reflect on:
  - How climate change and sea level rise will impact their lives and community.
  - What they would like their future in Hawai‘i to look like as we adapt to rising sea level.
- Have students illustrate both reflections and include people and the environment and connections between society, science and technology.
- In class, have students reconvene in their groups and present their illustrations.
- Have students discuss the images and what type of vision they, as a group, have for Hawai‘i. Are there similarities or differences?

10. Challenge students to create their Community Action Plan.

- Distribute six Task Cards and a piece of chart paper to each group.
- Have students draw a horizontal timeline along the length of the chart paper and list today’s date on the left and the date that they would expect to complete their tasks on the right.
- Using **Learning Log 11** as a template, have students transfer the information to each Task Card.
- In their groups, have them discuss who would be responsible for carrying out each task and what types of materials are needed to complete each task. Have students record this information on the Task Cards and Learning Log.
- Have students place each Task Card along the timeline in a logical order.
- Ask them to review the overall placement and information on each Task Card and determine if they agree with the plan that they have created.
  - Does the plan reflect their group’s vision for Hawai‘i?
  - Does it consider the environmental and human factors?
- Have students prepare a presentation of their Community Action Plan. The presentation could include a PowerPoint presentation, poster, or public service announcement. The plan should creatively express their group’s vision, final timeline, and information on the Task Cards. Check with groups to be sure that each student has a role in explaining a portion of the plan to the community.

11. Have students present their Community Action Plan to the class and community during a hō‘ike.

- Set a date for students to share their unit culminating projects with others in the school or community and send out announcements, including invitations to people that students interviewed during the unit.
- Have students present their Community Action Plans as a group during the hō‘ike.

12. Wrap up the unit.

- Administer the Unit Post-assessment (provided in Unit Introduction). Compare scores with Pre-assessment and note any benchmarks where students may need further work or where clarification of concepts is needed.
- Distribute a copy of the Self-Assessment Rubric to each student and ask everyone to complete it.
- Discuss their feedback and what individuals can do to promote successful teamwork.
- Congratulate groups for their hard work to create a Community Action Plan for sea level rise in their community.

Extending the Learning

- Go over the “Adapting to a Changing Climate” flipchart and booklet with students. As you move through the flipchart, compare Micronesia to Hawai‘i. Discuss what works for their communities and what can be used for Hawai‘i’s communities.

- Have students write letters or submit media pieces to government officials. Have them include their Community Action Plans in the information and persuade officials to take action.

References

McFadzien, D., F. Areki, T. Biuvakadua, and M. Fiu. *Climate Witness: Community Toolkit*. World Wildlife Fund: Suva, Fiji. 2005.

Gombos, M., Atkinson, S., and Wongbusarakum, S. *Adapting to a Changing Climate*. 2010. Accessed December 4, 2011. http://www.cakex.org/virtual-library/3439.

Resource

Adapting to a Changing Climate has flipcharts, facilitator’s notes, and a booklet that was created for Micronesian communities to address climate change. These resources are excellent materials in presenting another community’s climate change action plan to your students. Accessible at http://www.cakex.org/virtual-library/3439.

LEARNING LOG 10: ROOT CAUSE ANALYSIS

GROUP MEMBER'S NAMES_____DATE_____

1. Working in your group, draw a picture of a tree with branches and roots.
2. In the trunk, place a Post-it that describes a problem facing your community due to predicted sea level rise.
3. Answer the question, "Why has this problem occurred?" or "Why will it likely occur?" and write one cause for the problem on a Post-it and place each Post-it within the roots of your tree.
4. Answer the question, "What happened or (will happen)?" and write each effect on a Post-it and place each Post-it within the branches.
5. If you identify causes or effects that occur because of the primary cause or effect, then write these down as secondary roots or branches, respectively.
6. Draw a flow chart that illustrates your tree's root cause analysis for each problem below. You may use additional sheets of paper if necessary.

LEARNING LOG 11: SUN RAY EXERCISE

GROUP MEMBER'S NAMES_____**DATE**_____

Root Cause of the Problem	Actions Needed to Achieve the Solution	Solution	Action's Effectiveness		
			Low	Medium	High

Task Cards

Root Cause: **Action:** **Person Responsible:** **Materials Needed:** **Priority:** Low Medium High **Card Number:**	**Root Cause:** **Action:** **Person Responsible:** **Materials Needed:** **Priority:** Low Medium High **Card Number:**
Root Cause: **Action:** **Person Responsible:** **Materials Needed:** **Priority:** Low Medium High **Card Number:**	**Root Cause:** **Action:** **Person Responsible:** **Materials Needed:** **Priority:** Low Medium High **Card Number:**
Root Cause: **Action:** **Person Responsible:** **Materials Needed:** **Priority:** Low Medium High **Card Number:**	**Root Cause:** **Action:** **Person Responsible:** **Materials Needed:** **Priority:** Low Medium High **Card Number:**

Self-Assessment Rubric

Name: _____ **Date:** _____

Place a check in the box that matches your performance as a group member. Add up your points and answer the questions below.

My Actions	Maikaʻi loa! Excellent 4 points	Maikaʻi Good 3 points	ʻAno Maikaʻi Okay 2 points	Auē! Not so good 1 point
I did my best work for the team. It was in-depth, organized, neat and creative!				
I helped others when they needed my *kōkua*.				
I finished my work on time.				
I listened to others' ideas without being critical.				
I gave positive feedback to my team members.				
I asked for and used feedback from others.				
I think we did an awesome job as a team.				

Total Score _____

Explain what your contribution was to the team.

What was difficult for you in working with your team? Why?

How could you improve and help your team to be more effective? (If you need more room, use the other side of this sheet.)