A High School Curriculum Framework for Teaching about Alaska Ocean Climate Change

Big Ideas:

1. What is the evidence that the climate is changing rapidly in the Arctic?
2. How is the ocean a major influence on weather and climate?
3. How will Arctic warming affect global climate systems?
4. How will the ocean in the Arctic be affected by climate change?
5. What are the effects of climate change on animals, vegetation and productivity?
6. How will people and their environment be affected by climate change?
7. How do people affect the oceans and atmosphere?

The draft framework consists of two components:

1. **Matrix.** A matrix aligning the big ideas with concepts, essential principles of ocean, climate, and earth science; and state and national science standards.

2. **Climate-Ocean Concept Maps.** Concept maps about the transfer and storage of heat, carbon, and water have been developed using the COSEE-Ocean Systems Concept Mapper and are online at http://cosee.umaine.edu/cfuser/cmb/index.cfmh

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Alignment with Essential Principles & Standards

Climate Science Literacy is an understanding of your influence on climate and climate's influence on you and society. In addition to understanding the essential principles of Earth's climate system, the climate-literate person: 1) knows how to assess scientifically credible information about climate, 2) communicates about climate and climate change in a meaningful way, and 3) is able to make informed and responsible decisions with regard to actions that may affect climate. This framework aligns the Essential Principles of Climate Science with science education standards. The complete set of Principles and Guiding Principles for Informed Climate Decisions can be found at: http://downloads.climatescience.gov/Literacy/Climate%20Literacy%20Booklet%20Low-Res.pdf

Ocean literacy is an understanding of the ocean's influence on you – and your influence on the ocean. In addition to understanding Essential Principles and Fundamental Concepts about the functioning of the ocean, an ocean-literate person: 1) can communicate about the ocean in a meaningful way and 2) is able to make informed and responsible decisions regarding the ocean and its resources. This framework aligns the Essential Principles of Ocean Sciences with science education standards. The Principles can be found at: http://www.coexploration.org/oceanliteracy/documents/OceanLitChart.pdf

Earth Science Literacy Principles: http://www.earthscienceliteracy.org/es_literacy_22may09.pdf

Benchmarks, National Science Standards (NSES) http://www.project2061.org/publications/bsl/online/index.php?txtRef=http%3A%2F%2Fwww.project2061.org%2Fpublications%2Fbsl%2F&txtURIOld=%2Fpublications%2Fbsl%2Fonline%2Fbolintro.htm

Benchmark language from Science for All Americans (SFAA): http://www.project2061.org/publications/sfaa/online/sfaatoc.htm

Alaska State Science Standards Grade Level Expectations (GLEs): http://www.eed.state.ak.us/tls/assessment/GLEHome.html

Scope-and-Sequence Concept Diagrams

The Alaska framework was developed prior to the completion of a K-12 Scope and Sequence Concept Diagrams for the Ocean Literacy Principles by COSEE-California and COSEE-West. These can be found at:
http://www.coexploration.org/oceanliteracy/usa/ocean_science_literacy/scope_and_sequence/home.html

1. **What is the evidence that the climate is changing rapidly in the Arctic?**

Topics to Explore	• Melting ice (land and sea) • Melting permafrost • Increased extreme weather events • Change in air and ocean temperature **Other Related Topics:** • El Nino • Unpredictability • Erosion • Forest fires • Lakes drying up • Changing phenology • Salmon disease, movement
Related Climate Literacy Principles	**CL4. Climate varies over space and time through both natural and man-made processes.** CL4 A. Climate is determined by the long-term pattern of temperature and precipitation averages and extremes at a location. Climate descriptions can refer to areas that are local, regional, or global in extent. Climate can be described for different time intervals, such as decades, years, seasons, months, or specific dates of the year. CL4 D. Scientific observations indicate that global climate has changed in the past, is changing now, and will change in the future. The magnitude and direction of this change is not the same at all locations on Earth. **CL5. Our understanding of the climate system is improved through observations, theoretical studies, and modeling.** CL5A. The components and processes of Earth's climate system are subject to the same physical laws as the rest of the Universe. Therefore, the behavior of the climate system can be understood and predicted through careful, systematic study. CL5 B. Environmental observations are the foundation for understanding the climate system. From the bottom of the ocean to the surface of the Sun, instruments on weather stations, buoys, satellites, and other platforms collect climate data. To learn about past climates, scientists use natural records, such as tree rings, ice cores, and sedimentary layers. Historical observations, such as native knowledge and personal journals, also document past climate change. CL5 C. Observations, experiments, and theory are used to construct and refine computer models that represent the climate system and make predictions about its future behavior. Results from these models lead to better understanding of the linkages between the atmosphere-ocean system and climate conditions and inspire more observations and experiments. Over time, this iterative process will

	result in more reliable projections of future climate conditions. CL5 D. Our understanding of climate differs in important ways from our understanding of weather. Climate scientists' ability to predict climate patterns months, years, or decades into the future is constrained by different limitations than those faced by meteorologists in forecasting weather days to weeks into the future.[1] CL5 E. Scientists have conducted extensive research on the fundamental characteristics of the climate system and their understanding will continue to improve. Current climate change projections are reliable enough to help humans evaluate potential decisions and actions in response to climate change.
Related Ocean Literacy Principles	None
Related Earth Science Literacy Principles	**Earth scientists use repeatable observations and testable ideas to understand and explain our planet**. **1.3 Earth science investigations take many different forms.** Earth scientists do reproducible experiments and collect multiple lines of evidence. This evidence is taken from field, analytical, theoretical, experimental, and modeling studies. **1.5 Earth scientists use their understanding of the past to forecast the Earth's future.** Earth science research tells us how the Earth functioned in the past under conditions not seen today and how conditions are likely to change in the future. **1.6 Earth scientists construct models of Earth and its processes that best explain the available geological evidence.** These models undergo rigorous scrutiny and testing by collaborating and competing groups of scientists around the world. Earth science research documents are subjected to rigorous peer review before they are published in science journals.
Related Benchmarks **For Science Literacy**	**Scientific Inquiry** Sometimes, scientists can control conditions in order to obtain evidence. When that is not possible, practical, or ethical, they try to observe as wide a range of natural occurrences as possible to discern patterns. 1B/H3* **The Earth** The earth's climates have changed in the past, are currently changing, and are expected to change in the future, primarily due to changes in the amount of light reaching places on the earth and the composition of the atmosphere. The burning of fossil fuels in the last century has increased the amount of greenhouse gases in the atmosphere, which has contributed to Earth's warming. 4B/H6** (SFAA)
Related	SA1 Students develop an understanding of the processes and applications of scientific

Alaska Standards	inquiry by (grades 9, 10, 11) SA1.1 asking questions, predicting observing, describing, measuring, classifying, making generalizations, analyzing data, developing models, inferring, and communicating[1]
Related Notes & Activities	Prior knowledge of the following Climate Literacy Principle Concepts: CL4B, CL4C Prior knowledge of the following Ocean Literacy Principle Concepts: OL7A- F Tools to use: • Real-time data • Graphs • Local observations, past and present

[1] This standard/GLE applies to all sections.

2. How is the ocean a major influence on weather and climate?

Topics to Explore	• Absorption, storage, movement: heat and carbon • Absorption of heat/heat capacity • CO2 absorption and buffering • Role in water cycle • Circulation patterns **Other Related Topics** • Primary productivity and associated turbidity • Water cycle
Related Climate Literacy Principles	**CL2. Climate is regulated by complex interactions among components of the Earth system.** CL2A. Earth's climate is influenced by interactions involving the Sun, ocean, atmosphere, clouds, ice, land, and life. Climate varies by region as a result of local differences in these interactions. CL2 B. Covering 70% of Earth's surface, the ocean exerts a major control on climate by dominating Earth's energy and water cycles. It has the capacity to absorb large amounts of solar energy. Heat and water vapor are redistributed globally through density-driven ocean currents and atmospheric circulation. Changes in ocean circulation caused by tectonic movements or large influxes of fresh water from melting polar ice can lead to significant and even abrupt changes in climate, both locally and on global scales.
Related Ocean Literacy Principles	**OL1. Earth has one big ocean with many features.** OL1c Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of the Earth's rotation (Coriolis effect), the Sun, and water density differences. The shape of ocean basins and adjacent land masses influence the path of circulation. OL1d Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change. It changes as ice caps on land melt or grow. It also changes as sea water expands and contracts when ocean water warms and cools. OL1g The ocean is connected to major lakes, watersheds and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments and pollutants from watersheds to estuaries and to the ocean. **OL3. Ocean is a major influence on weather and climate.** OL3 a The ocean controls weather and climate by dominating the Earth's energy, water and carbon systems.

	OL3 b The ocean absorbs much of the solar radiation reaching Earth. The ocean loses heat by evaporation. This heat loss drives atmospheric circulation when, after it is released into the atmosphere as water vapor, it condenses and forms rain. Condensation of water evaporated from warm seas provides the energy for hurricanes and cyclones. OL3 c The El Niño Southern Oscillation causes important changes in global weather patterns because it changes the way heat is released to the atmosphere in the Pacific. OL3 d Most rain that falls on land originally evaporated from the tropical ocean. OL3 e The ocean dominates the Earth's carbon cycle. Half the primary productivity on Earth takes place in the sunlit layers of the ocean and the ocean absorbs roughly half of all carbon dioxide added to the atmosphere. OL3 f The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water. OL3 g Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years. **OL6. The ocean and humans are inextricably interconnected.** OL6 a The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.
Related Earth Science Literacy Principles	**Big Idea #3: Earth is a complex system of interacting rock, water, air, and life. 3.7 Changes in part of one system can cause new changes to that system or to other systems, often in surprising and complex ways.** These new changes may take the form of" feedbacks" that can increase or decrease the original changes and can be unpredictable and/or irreversible. A deep knowledge of how most feedbacks work within and between Earth's systems is still lacking. **3.8 Earth's climate is an example of how complex interactions among systems can result in relatively sudden and significant changes.** The geologic record shows that interactions among tectonic events, solar inputs, planetary orbits, ocean circulation, volcanic activity, glaciers, vegetation, and human

	activities can cause appreciable, and in some cases rapid, changes to global and regional patterns of temperature and precipitation.
Related Benchmarks	**The Physical Setting:** The Earth: Transfer of thermal energy between the atmosphere and the land or oceans produces temperature gradients in the atmosphere and the oceans. Regions at different temperatures rise or sink or mix, resulting in winds and ocean currents. These winds and ocean currents, which are also affected by the earth's rotation and the shape of the land, carry thermal energy from warm to cool areas. 4B/H2* Climatic conditions result from latitude, altitude, and from the position of mountain ranges, oceans, and lakes. Dynamic processes such as cloud formation, ocean currents, and atmospheric circulation patterns influence climates as well. 4B/H5** (NSES) In a fluid, regions that have different temperatures have different densities. The action of a gravitational force on regions of different densities causes them to rise or fall, creating currents that contribute to the transfer of energy. 4E/H8** (BSL)
Related Alaska GLEs	none
Related Activities	

3. How will Arctic warming affect global climate systems?

Will changes in the Arctic trigger climate shifts beyond the Arctic?

Topics to Explore	• Albedo • Feedback loops • Arctic connections to global current patterns • Weather • Melting ice contribution to sea level rise • Methane emissions - Frozen hydrates and tundra **Other Related Topics:** • Weather patterns?
Related Climate Literacy Principles	**CL1. The Sun is the primary source of energy for Earth's climate system.** CL1A. Sunlight reaching the Earth can heat the land, ocean, and atmosphere. Some of that sunlight is reflected back to space by the surface, clouds, or ice. Much of the sunlight that reaches Earth is absorbed and warms the planet. CL1D. Gradual changes in Earth's rotation and orbit around the Sun change the intensity of sunlight received in our planet's polar and equatorial regions. For at least the last 1 million years, these changes occurred in 100,000-year cycles that produced ice ages and the shorter warm periods between them. **CL2. Climate is regulated by complex interactions among components of the Earth system.** CL2 B. Covering 70% of Earth's surface, the ocean exerts a major control on climate by dominating Earth's energy and water cycles. It has the capacity to absorb large amounts of solar energy. Heat and water vapor are redistributed globally through density-driven ocean currents and atmospheric circulation. Changes in ocean circulation caused by tectonic movements or large influxes of fresh water from melting polar ice can lead to significant and even abrupt changes in climate, both locally and on global scales. CL2C. The amount of solar energy absorbed or radiated by Earth is modulated by the atmosphere and depends on its composition. Greenhouse gases—such as water vapor, carbon dioxide, and methane—occur naturally in small amounts and absorb and release heat energy more efficiently than abundant atmospheric gases like nitrogen and oxygen. Small increases in carbon dioxide concentration have a large effect on the climate system. CL2F. The interconnectedness of Earth's systems means that a significant

	change in any one component of the climate system can influence the equilibrium of the entire Earth system. Positive feedback loops can amplify these effects and trigger abrupt changes in the climate system. These complex interactions may result in climate change that is more rapid and on a larger scale than projected by current climate models. **CL4. Climate varies over space and time through both natural and man-made processes.** CL4E. Based on evidence from tree rings, other natural records, and scientific observations made around the world, Earth's average temperature is now warmer than it has been for at least the past 1,300 years. Average temperatures have increased markedly in the past 50 years, especially in the North Polar Region. CL4G. Natural processes that remove carbon dioxide from the atmosphere operate slowly when compared to the processes that are now adding it to the atmosphere. Thus, carbon dioxide introduced into the atmosphere today may remain there for a century or more. Other greenhouse gases, including some created by humans, may remain in the atmosphere for thousands of years. **CL7. Climate change will have consequences for the Earth system and human lives.** CL7C. Incidents of extreme weather are projected to increase as a result of climate change. Many locations will see a substantial increase in the number of heat waves they experience per year and a likely decrease in episodes of severe cold. Precipitation events are expected to become less frequent but more intense in many areas, and droughts will be more frequent and severe in areas where average precipitation is projected to decrease.[2]
Related Ocean Literacy Principles	**OL3. Ocean is a major influence on weather and climate.** OL3g. Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years. **OL5. The ocean supports a great diversity of life and ecosystems.** OL5d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.
Related Earth	**Big Idea #3: Earth is a complex system of interacting rock, water, air, and**

Science Literacy Principles	**life.** **3.7 Changes in part of one system can cause new changes to that system or to other systems, often in surprising and complex ways.** These new changes may take the form of "feedbacks" that can increase or decrease the original changes and can be unpredictable and/or irreversible. A deep knowledge of how most feedbacks work within and between Earth's systems is still lacking. **3.8 Earth's climate is an example of how complex interactions among systems can result in relatively sudden and significant changes.** The geologic record shows that interactions among tectonic events, solar inputs, planetary orbits, ocean circulation, volcanic activity, glaciers, vegetation, and human activities can cause appreciable, and in some cases rapid, changes to global and regional patterns of temperature and precipitation.
Related Benchmarks	**The Physical Setting: The Earth** Greenhouse gases in the atmosphere, such as carbon dioxide and water vapor, are transparent to much of the incoming sunlight but not to the infrared light from the warmed surface of the earth. When greenhouse gases increase, more thermal energy is trapped in the atmosphere, and the temperature of the earth increases the light energy radiated into space until it again equals the light energy absorbed from the sun. 4B/H4** (SFAA)
Related Alaska Standards	none
Related Activities	

4. How will the ocean (physical and chemical systems) in the Arctic be affected by climate change?

Topics to Explore	• More open water, less ice • Higher SSTs • Changes in turbidity/reflectivity

	• Sea level change • Changes in circulation • Changes in water chemistry, acidification **Other Related Topics:** • Possible disruption of cycles • Changes in food web, productivity, biodiversity • Changes in freshwater flow • Changes in currents and and nearshore salinity • Animal movement • Development
Related Climate Literacy Principles	**CL4. Climate varies over space and time through both natural and man-made processes.** CL4E. Based on evidence from tree rings, other natural records, and scientific observations made around the world, Earth's average temperature is now warmer than it has been for at least the past 1,300 years. Average temperatures have increased markedly in the past 50 years, especially in the North Polar Region. **CL6. Human activities are impacting the climate system.** CL6D. Growing evidence shows that changes in many physical and biological systems are linked to human-caused global warming.[3] Some changes resulting from human activities have decreased the capacity of the environment to support various species and have substantially reduced ecosystem biodiversity and ecological resilience. **CL7. Climate change will have consequences for the Earth system and human lives.** CL7A. Melting of ice sheets and glaciers, combined with the thermal expansion of seawater as the oceans warm, is causing sea level to rise. Seawater is beginning to move onto low-lying land and to contaminate coastal fresh water sources and beginning to submerge coastal facilities and barrier islands. Sea-level rise increases the risk of damage to homes and buildings from storm surges such as those that accompany hurricanes. CL7D. The chemistry of ocean water is changed by absorption of carbon dioxide from the atmosphere. Increasing carbon dioxide levels in the atmosphere is causing ocean water to become more acidic, threatening the survival of shell-building marine species and the entire food web of which they are a part. CL7E. Ecosystems on land and in the ocean have been and will continue to be disturbed by climate change. Animals, plants, bacteria, and viruses will migrate to new areas with favorable climate conditions. Infectious diseases

	and certain species will be able to invade areas that they did not previously inhabit.
Related Ocean Literacy Principles	**OL1. Earth has one big ocean with many features.** OL1c Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of the Earth's rotation (Coriolis effect), the Sun, and water density differences. The shape of ocean basins and adjacent land masses influence the path of circulation. OL1d Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change. It changes as ice caps on land melt or grow. It also changes as sea water expands and contracts when ocean water warms and cools. OL1e Most of Earth's water (97%) is in the ocean. Seawater has unique properties: it is saline, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic. The salt in seawater comes from eroding land, volcanic emissions, reactions at the seafloor, and atmospheric deposition. **OL2. Ocean and life in the ocean shape the features of the Earth.** OL2b Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land. **OL5. The ocean supports a great diversity of life and ecosystems.** OL5f Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert. OL5h Tides, waves and predation cause vertical zonation patterns along the shore, influencing the distribution and diversity of organisms.
Related Earth Science Literacy Principles	**Big Idea #3: Earth is a complex system of interacting rock, water, air, and life. 3.7 Changes in part of one system can cause new changes to that system or to other systems, often in surprising and complex ways.** These new changes may take the form of "feedbacks" that can increase or decrease the original changes and can be unpredictable and/or irreversible. A deep

	knowledge of how most feedbacks work within and between Earth's systems is still lacking. **3.8 Earth's climate is an example of how complex interactions among systems can result in relatively sudden and significant changes.** The geologic record shows that interactions among tectonic events, solar inputs, planetary orbits, ocean circulation, volcanic activity, glaciers, vegetation, and human activities can cause appreciable, and in some cases rapid, changes to global and regional patterns of temperature and precipitation.
Related Benchmarks	**The Physical Setting:** The Earth: Transfer of thermal energy between the atmosphere and the land or oceans produces temperature gradients in the atmosphere and the oceans. Regions at different temperatures rise or sink or mix, resulting in winds and ocean currents. These winds and ocean currents, which are also affected by the earth's rotation and the shape of the land, carry thermal energy from warm to cool areas. 4B/H2* Energy Transformations: In a fluid, regions that have different temperatures have different densities. The action of a gravitational force on regions of different densities causes them to rise or fall, creating currents that contribute to the transfer of energy. 4E/H8** (BSL)
Related Alaska Standards	none
Related Activities	

5. What are the effects on animals, vegetation and productivity?

Topics to Explore	How will animals in the arctic be affected by climate change?
	
	"Adapt, move, or perish"
	
	(Emphasis on effects with global significance)
	
	• Loss of physical habitat
	  o Sea ice
	  o Walruses, seals, polar bears, eiders, salmon habitat
	• Changing location of hotspots
	• Niches – adaptation, movement, or die. Physical habitat (chemistry), food, - salmon
	• Food web effects
	• Mismatch
	• Diseases – salmon – water temp.
	• Extinction
	• Ecosystem regulation
	• Tundra to shrub
	Other Related Topics:
	
	• Phenology
	• Ecosystem regulation
	• Timing of bloom
	• Gobal significance of changes on arctic animals infestations
	• Invasive species

Related Climate Literacy Principles	**CL2. Climate is regulated by complex interactions among components of the Earth system.** CL2F. The interconnectedness of Earth's systems means that a significant change in any one component of the climate system can influence the equilibrium of the entire Earth system. Positive feedback loops can amplify these effects and trigger abrupt changes in the climate system. These complex interactions may result in climate change that is more rapid and on a larger scale than projected by current climate models. **CL3. Life on Earth depends on, is shaped by, and affects climate.** CL3A. Individual organisms survive within specific ranges of temperature, precipitation, humidity, and sunlight. Organisms exposed to climate conditions outside their normal range must adapt or migrate, or they will perish. CL3C. Changes in climate conditions can affect the health and function of ecosystems and the survival of entire species. The distribution patterns of fossils show evidence of gradual as well as abrupt extinctions related to climate change in the past.

	CL7. Climate change will have consequences for the Earth system and human lives. CL7D. The chemistry of ocean water is changed by absorption of carbon dioxide from the atmosphere. Increasing carbon dioxide levels in the atmosphere is causing ocean water to become more acidic, threatening the survival of shell-building marine species and the entire food web of which they are a part. CL7E. Ecosystems on land and in the ocean have been and will continue to be disturbed by climate change. Animals, plants, bacteria, and viruses will migrate to new areas with favorable climate conditions. Infectious diseases and certain species will be able to invade areas that they did not previously inhabit.
Related Ocean Literacy Principles	**OL3. Ocean is a major influence on weather and climate.** OL3e The ocean dominates the Earth's carbon cycle. Half the primary productivity on Earth takes place in the sunlit layers of the ocean and the ocean absorbs roughly half of all carbon dioxide added to the atmosphere. **OL5. The ocean supports a great diversity of life and ecosystems.** OL5b Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles. OL5f Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.
Related Earth Science Literacy Principles	none
Related Benchmarks	**The Physical Setting: The Earth** Although the earth has a great capacity to absorb and recycle materials naturally, ecosystems have only a finite capacity to withstand change without experiencing major ecological alterations that may also have adverse effects on human activities. 4B/H9** (SFAA) **The Living Environment: Interdependence of Life** If a disturbance such as flood, fire, or the addition or loss of species occurs, the

	ecosystem may return to a system similar to the original one, or it may take a new direction, leading to a very different type of ecosystem. Changes in climate can produce very large changes in ecosystems. 5D/H2*
Related Alaska Standards	SC3 Students develop an understanding that all organisms are linked to each other and their physical environments through the transfer and transformation of matter and energy by: a. (10) (11) SC3.1 relating the carbon cycle to global climate change b. (11) SC3.2 analyzing the potential impacts of changes (e.g. climate change, habitat loss/gain, cataclysms, human activities) within an ecosystem.
Related Activities	

6. How will people and their environment be affected by climate change?

Topics to Explore	Changes in ecosystems • Impacts to subsistence/culture, agriculture, fisheries and other food sources for humans • Health and disease Sea level rise, erosion, and extreme weather events • Damage to infrastructure • Displacement of people • Changes to transportation (roads and waterways) • Changes to navigation and harbors **Other Related Topics:** • Recreation • Agriculture
Related Climate Literacy Principles	**CL3. Life on Earth depends on, is shaped by, and affects climate.** CL3D. A range of natural records shows that the last 10,000 years have been an unusually stable period in Earth's climate history. Modern human societies developed during this time. The agricultural, economic, and transportation systems we rely upon are vulnerable if the climate changes significantly. **CL7. Climate change will have consequences for the Earth system and human lives.** CL7A. Melting of ice sheets and glaciers, combined with the thermal expansion of seawater as the oceans warm, is causing sea level to rise. Seawater is beginning to move onto low-lying land and to contaminate coastal fresh water sources and beginning to submerge coastal facilities and barrier islands. Sea-level rise increases the risk of damage to homes and buildings from storm surges such as those that accompany hurricanes. CL7b. Climate plays and important role in the global distribution of freshwater resources. Changing precipitation patterns and temperature conditions will alter the distribution and availability of freshwater resources, reducing reliable access to water for many people and their crops. Winter snowpack and mountain glaciers that provide water for human use are declining as a result of global warming. CL7C. Incidents of extreme weather are projected to increase as a result of climate change. Many locations will see a substantial increase in the number of heat waves they experience per year and a likely decrease in episodes of severe cold. Precipitation events are expected to become less frequent but more intense in many areas, and droughts will be more frequent and severe in areas where average precipitation is projected to decrease.[2]CLa. CL7d. The chemistry of ocean water is changed by absorption of carbon dioxide from the atmosphere. Increasing carbon dioxide levels in the atmosphere is causing ocean water to become more acidic, threatening the survival of shell-building marine species and the entire food web of which they are a part. CL7E. Ecosystems on land and in the ocean have been and will continue to be disturbed by climate change. Animals, plants, bacteria, and viruses will migrate to new

	areas with favorable climate conditions. Infectious diseases and certain species will be able to invade areas that they did not previously inhabit. CL 7f. Human health and mortality rates will be affected to different degrees in specific regions of the world as a result of climate change. Although cold-related deaths are predicted to decrease, other risks are predicted to rise. The incidence and geographical range of climate-sensitive infectious diseases – such as malaria, dengue fever, and tick-borne diseases – will increase. Drought-reduced crop yields, degraded air and water quality, and increased hazards in coastal and low-lying areas will contribute to unhealthy conditions, particularly for the most vulnerable populations.
Related Ocean Literacy Principles	**OL6. The ocean and humans are inextricably interconnected.** OLD Much of the world's population lives in coastal areas. OL6F Coastal regions are susceptible to natural hazards (tsunamis, hurricanes, cyclones, sea level change, and storm surges.
Related Earth Science Literacy Principles	none
Related Benchmarks	**The Physical Setting: The Earth** Although the earth has a great capacity to absorb and recycle materials naturally, ecosystems have only a finite capacity to withstand change without experiencing major ecological alterations that may also have adverse effects on human activities. 4B/H9** (SFAA) **The Living Environment: Interdependence of Life** If a disturbance such as flood, fire, or the addition or loss of species occurs, the ecosystem may return to a system similar to the original one, or it may take a new direction, leading to a very different type of ecosystem. Changes in climate can produce very large changes in ecosystems. 5D/H2*
Related Alaska Standards	SC3 Students develop an understanding that all organisms are linked to each other and their physical environments through the transfer and transformation of matter and energy by: a. (10) (11) SC3.1 relating the carbon cycle to global climate change b. (11) SC3.2 analyzing the potential impacts of changes (e.g. climate change, habitat loss/gain, cataclysms, human activities) within an ecosystem.

Related Activities	

7. How do people affect the oceans and atmosphere?

Topics to Explore	• Greenhouse gas emissions, CO2, acidification
	• CO2 --- ocean acidification higher temperatures
	• Altered vegetation patterns
	  o Reduced consumption
	  o Change reflectivity (pavement)
	• Responsibility/advocacy
	  o Laws, regulations
	  o Reduced use of fossil fuels
	  o Reduced consumption
	• Erosion
	Other Related Topics:
	
	• Habitat alteration
	• Pollution
	• Consumption of resources,
	  o Effects on food web, Population growth

Related Climate Literacy Principles	**CL2. Climate is regulated by complex interactions among components of the Earth system.** CL2C. The amount of solar energy absorbed or radiated by Earth is modulated by the atmosphere and depends on its composition. Greenhouse gases—such as water vapor, carbon dioxide, and methane—occur naturally in small amounts and absorb and release heat energy more efficiently than abundant atmospheric gases like nitrogen and oxygen. Small increases in carbon dioxide concentration have a large effect on the climate system. CL2E. Airborne particulates, called "aerosols," have a complex effect on Earth's energy balance: they can cause both cooling, by reflecting incoming sunlight back out to space, and warming, by absorbing and releasing heat energy in the atmosphere. Small solid and liquid particles can be lofted into the atmosphere through a variety of natural and man-made processes, including volcanic eruptions, sea spray, forest fires, and emissions generated through human activities. **CL3. Life on Earth depends on, is shaped by, and affects climate.** CL3B. The presence of small amounts of heat-trapping greenhouse gases in the atmosphere warms Earth's surface, resulting in a planet that sustains liquid water and life. CL3E. Life—including microbes, plants, and animals and humans—is a major driver of the global carbon cycle and can influence global climate by modifying the chemical makeup of the atmosphere. The geologic record shows that life has significantly altered the atmosphere during Earth's history.

	CL4. Climate varies over space and time through both natural and man-made processes. CL4F. Natural processes driving Earth's long-term climate variability do not explain the rapid climate change observed in recent decades. The only explanation that is consistent with all available evidence is that human impacts are playing an increasing role in climate change. Future changes in climate may be rapid compared to historical changes. **CL6. Human activities are impacting the climate system.** CL6A. The overwhelming consensus of scientific studies on climate indicates that most of the observed increase in global average temperatures since the latter part of the 20th century is very likely due to human activities, primarily from increases in greenhouse gas concentrations resulting from the burning of fossil fuels.[2] CL6B. Emissions from the widespread burning of fossil fuels since the start of the Industrial Revolution have increased the concentration of greenhouse gases in the atmosphere. Because these gases can remain in the atmosphere for hundreds of years before being removed by natural processes, their warming influence is projected to persist into the next century. CL6C. Human activities have affected the land, oceans, and atmosphere, and these changes have altered global climate patterns. Burning fossil fuels, releasing chemicals into the atmosphere, reducing the amount of forest cover, and rapid expansion of farming, development, and industrial activities are releasing carbon dioxide into the atmosphere and changing the balance of the climate system. CL6D. Growing evidence shows that changes in many physical and biological systems are linked to human-caused global warming.[3] Some changes resulting from human activities have decreased the capacity of the environment to support various species and have substantially reduced ecosystem biodiversity and ecological resilience. CL6E. Scientists and economists predict that there will be both positive and negative impacts from global climate change. If warming exceeds 2 to 3°C (3.6 to 5.4°F) over the next century, the consequences of the negative impacts are likely to be much greater than the consequences of the positive impacts.
Related Ocean Literacy Principles	**OL6. The ocean and humans are inextricably interconnected.** OLD Much of the world's population lives in coastal areas. OL6E Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (point source, non-point source, and noise pollution) and physical modifications (changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean. OL6G Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

	OL7. The ocean is largely unexplored. OL7C Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.
Related Earth Science Literacy Principles	**Big Idea #9: Humans significantly alter the Earth.** **9.3 Humans cause global climate change through fossil fuel combustion, land-use changes, agricultural practices, and industrial processes.** Consequences include melting glaciers and permafrost, rising sea levels, shifting precipitation patterns, increased forest fires, more extreme weather, and the disruption of global ecosystems. **9.8 Earth scientists document and seek to understand the impacts of humans on global change over short and long time spans.** Many of these human impacts on Earth's systems are not reversible over human lifetimes, but through human cooperation their impacts on future generations can be lessened and even reversed. **9.9 An Earth science literate public, informed by current and accurate scientific understanding of Earth, is critical to the promotion of good stewardship, sound policy, and international cooperation.** Earth science education is important for individuals of all ages, backgrounds, and nationalities.
Related Benchmarks	**The Nature of Technology: Issues in Technology** The human species has a major impact on other species in many ways: reducing the amount of the earth's surface available to those other species, interfering with their food sources, changing the temperature and chemical composition of their habitats, introducing foreign species into their ecosystems, and altering organisms directly through selective breeding and genetic engineering. 3C/H4 **The Physical Setting: The Earth** Although the earth has a great capacity to absorb and recycle materials naturally, ecosystems have only a finite capacity to withstand change without experiencing major ecological alterations that may also have adverse effects on human activities. 4B/H9** (SFAA) Greenhouse gases in the atmosphere, such as carbon dioxide and water vapor, are transparent to much of the incoming sunlight but not to the infrared light from the warmed surface of the earth. When greenhouse gases increase, more thermal energy

	is trapped in the atmosphere, and the temperature of the earth increases the light energy radiated into space until it again equals the light energy absorbed from the sun. 4B/H4** (SFAA) The earth's climates have changed in the past, are currently changing, and are expected to change in the future, primarily due to changes in the amount of light reaching places on the earth and the composition of the atmosphere. The burning of fossil fuels in the last century has increased the amount of greenhouse gases in the atmosphere, which has contributed to Earth's warming. 4B/H6** (SFAA)
Related Alaska Standards	SD3 Students develop an understanding of the cyclical changes controlled by energy from the sun and by Earth's position and motion in our solar system by: (10, 11) describing causes, effects, preventions and mitigations of human impact on the environment.
Related Activities	