CLIMATE LITERACY: The Essential Principles of Climate Science	Alaska Standards and GLEs	Analysis
1. THE SUN IS THE PRIMARY SOURCE OF ENERGY FOR EARTH'S CLIMATE SYSTEM.		
A. 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.	(5) SD3.2 Students develop an understanding of cyclic changes controlled by the energy from the sun and by Earth's position and motion in the Solar system by comparing heat absorption and loss by land and water.	Partial. All of interconnections likely not covered.
B. When Earth emits the same amount of energy as it absorbs, its energy budget is in balance, and its average temperature remains stable.		No
C. The tilt of Earth's axis relative to its orbit around the Sun results in predictable changes in the duration of daylight and the amount of sunlight received at any latitude throughout a year. These changes cause the annual cycle of seasons and associated temperature changes.	SD3 Students develop an understanding of cyclic changes controlled by the energy from the sun and by Earth's position and motion in the Solar system by (3) SD3.1 using recorded weather patterns (e.g., temperature, cloud cover, or precipitation) to make reasonable predictions (L) (4) SD 3.1 recognizing changes in daylight over time and its relationships to seasons. (10) (11) SD3.1 describing causes, effects, preventions, and mitigations of human impact on climate. (11) SD3.2 explaining the causes and effects related to phenomena (e.g., winds, Coriolis effect)	Covered
D. 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.	SD3 Students develop an understanding of cyclic changes controlled by the energy from the sun and by Earth's position and motion in the Solar system by (10) (11) SD3.1 describing causes, effects, preventions, and mitigations of human impact on climate. (11) SD3.2 explaining the causes and effects related to phenomena (e.g., winds, Coriolis effect)	Partial, may lack emphasis on long-term cycles.
E. A significant increase or decrease in the Sun's energy output would cause Earth to warm or cool. Satellite measurements taken over the past 30 years show that the Sun's energy output has changed only slightly and in both directions. These changes in the Sun's energy are thought to be too small to be the cause of the recent warming observed on Earth.	SD3 Students develop an understanding of cyclic changes controlled by the energy from the sun and by Earth's position and motion in the Solar system by (10) (11) SD3.1 describing causes, effects, preventions, and mitigations of human impact on climate. (11) SD3.2 explaining the causes and effects related to phenomena (e.g., winds, Coriolis effect)	Likely to be covered. Recent trend and significance to climate change may not covered.
2. CLIMATE IS REGULATED BY COMPLEX INTERACTIONS AMONG COMPONENTS OF THE EARTH SYSTEM.		
Alaska-specific concepts: (1) Warming of the atmosphere and Arctic Ocean will affect the global climate system.	SD1 Students develop an understanding of geochemical cycles by (10) SD1.2 describing their interrelationships (i.e., water	Partial. Interrelationships of biogeochemical cycles

(2) The physical and chemical processes in the ocean surrounding Alaska will be affected by climate change.	cycle, carbon cycle, oxygen cycle) SD3 Students develop an understanding of cyclic changes controlled by the energy from the sun and by Earth's position and motion in the Solar system by (10) (11) SD3.1 describing causes, effects, preventions, and mitigations of human impact on climate. (11) SD3.2 explaining the causes and effects related to phenomena (e.g., winds, Coriolis effect)	with heat and energy movement, transport, and storage may not be emphasized.
A. 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.	SD3 Students develop an understanding of cyclic changes controlled by the energy from the sun and by Earth's position and motion in the Solar system (related GLEs)	Partial. Full scope of interactions unlikely to be covered.
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. **OL 3 The ocean is a major influence on weather and climate.** OL 3a. The ocean controls weather and climate by dominating the Earth's **energy, water and carbon systems**. OL3b. 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. OL 3e. The ocean dominates the Earth's **carbon** cycle. . . . The ocean absorbs roughly half of all carbon dioxide added to the atmosphere. OL 3f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving **heat, carbon and water.** OL3c. 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. OL3d. Most rain that falls on land originally evaporated from the tropical ocean. OL 3g Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years.	Concepts related to density-driven ocean currents, large influxes of fresh water from melting polar ice, changes in ocean circulation are particularly relevant to climate change impacts to Alaskan ecosystems and global climate change. The student demonstrates an understanding geochemical cycles by [3] SD1.2 describing the water cycle to show that water circulates through the crust, **oceans**, and atmosphere of Earth The student demonstrates an understanding of cycles influenced by energy from the sun and by Earth's position and motion in our solar system by [5] SD3.2 comparing heat absorption and loss by land and water [8] SD3.2 recognizing types of energy transfer (convection, conduction, and radiation) and how they affect weather. [10] SD1.2 describing their interrelationships (i.e., water cycle, carbon cycle, oxygen cycle)	No Partial. Ocean dominance of carbon, water, and carbon cycles and full scope of interactions in the geochemical and climate systems likely not covered.
C. The amount of solar energy absorbed or radiated by Earth is modulated by the atmosphere and depends on its composition.		No

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.		
D. The abundance of greenhouse gases in the atmosphere is controlled by biogeochemical cycles that continually move these components between their ocean, land, life, and atmosphere reservoirs. The abundance of carbon in the atmosphere is reduced through seafloor accumulation of marine sediments and accumulation of plant biomass and is increased through deforestation and the burning of fossil fuels as well as through other processes. OL 3f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water.	The student demonstrates an understanding of geochemical cycles by [10] SD1.2 describing their interrelationships (i.e., water cycle, carbon cycle, oxygen cycle)	Greenhouse gases and specific interactions of carbon cycle could be covered, but not necessarily.
E. 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.		No
F. 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.	*Relevant Alaska examples: change in albedo with melting sea ice, role of Arctic ocean fresh water flows in global thermohaline cycle; polar amplification of warming.*	No
3. LIFE ON EARTH DEPENDS ON, IS SHAPED BY, AND AFFECTS CLIMATE.		
Scaffolding Concepts	SC 2 Students develop an understanding of the structure, function, behavior, development, life cycles, and diversity of living organisms. (GLEs are aspects of this standard.) SC3 Students develop an understanding that all organisms are linked to each other and their physical environments through the transfer and transformation of energy. (Other GLEs are aspects of this standard, i.e., concepts related to food chains, food webs, trophic levels, energy flow and conservation of matter, behavior) [9] SC3.1 describing the carbon and nitrogen cycle within an ecosystem and how the continual input of energy from sunlight keeps the process going (L)	The overall concept could be covered and focus on interrelationships of life and climate, but not necessarily.

	[10][11] SC3.1 relating the carbon cycle to global climate change.	
A. 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.	(3) SA3.1 The student demonstrates an understanding that interactions with the environment provide an opportunity for understanding scientific concepts by (3) SA3.1 observing local conditions that determine which plants and/or animals survive. [4] SA3.1 identifying the local limiting factors (e.g., weather, human, influence, species interactions) that determine which plants and/or animals survive. [5] SA3.1 identifying the limiting factors (e.g., weather, human, influence, species interactions) that determine which plants and/or animals survive. [9] SC3.2 The student demonstrates an understanding that all organisms are linked to each other and their physical environments through the transfer and transformation of matter and energy by identifying dynamic factors (e.g., carrying capacity, limiting factors, biodiversity, and productivity) that affect population size.	Likely covered in relation to weather. Not covered in relation to climate. Relevant to impacts of climate change on Alaska ecosystems.
B. 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.		No
C. 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.	SC3 The student demonstrates an understanding that all organisms are linked to each other and their physical environments through the transfer and transformation of matter and energy by: [11] SC3.2 analyze the potential impact of changes (e.g., climate change, habitat loss/gain, cataclysm, human activities) within an ecosystem.	Climate change effects on Alaskan food webs and ecosystems is relevant but not necessarily covered.
D. 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.	*Impacts on economic and transportation (e.g., tundra travel, polar sea routes) systems are particularly relevant to Alaska.*	No
E. 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. OL3e. The ocean dominates the Earth's carbon cycle. Half the primary productivity on Earth takes place in the sunlit layers of the ocean . . .	SD3 Students develop an understanding of cyclic changes controlled by the energy from the sun and by Earth's position and motion in the Solar system by SC3 The student demonstrates an understanding that all organisms are linked to each other and their physical environments through the transfer and transformation of matter and energy by: (9) SC3.1 describing the carbon and nitrogen cycle within an ecosystem and how the continual input of energy from	Partial. Emphasis on life as a driver of the global carbon cycle and influence on global climate may not be emphasized.

	sunlight keeps the system going. (L) (10)(11) SC3.1 relating the carbon cycle to global climate change.	
4. CLIMATE varies over SPACE AND TIME THROUGH both NATURAL AND MAN-MADE PROCESSES.		
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.		No
B. Climate is not the same thing as weather. Weather is the minute-by-minute variable condition of the atmosphere on a local scale. Climate is a conceptual description of an area's average weather conditions and the extent to which those conditions vary over long time intervals.		No
C. Climate change is a significant and persistent change in an area's average climate conditions or their extremes. Seasonal variations and multi-year cycles (for example, the El Niño Southern Oscillation) that produce warm, cool, wet, or dry periods across different regions are a natural part of climate variability. They do not represent climate change.		No
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.		No
E. 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.**	*The accelerated rate of change in the North Polar region is particularly relevant to Alaska.*	No
F. 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.		No
G. 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.		No
5. OUR UNDERSTANDING OF THE CLIMATE SYSTEM IS improved THROUGH observations,		

THEORETICAL STUDIES, AND MODELING.		
	SA2 Students develop an understanding of the processes of science require integrity, logical reasoning, skepticism, openness, communication, and peer review. SG3 Students develop an understanding through that scientific knowledge is ongoing and subject to change as new evidence becomes available through experimental and/or observational confirmations.	Climate change research cold be addressed, but not necessarily.
A. 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.		No
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. more reliable projections of future climate conditions.	SA2 Students develop an understanding of the processes of science require integrity, logical reasoning, skepticism, openness, communication, and peer review. The student demonstrates an understanding of the attitudes and approaches to scientific inquiry by: [6] SA2.1 identifying and differentiating fact from opinion. [7] SA2.1 identifying and evaluating the sources used to support scientific statements. [10] SA2.1 Examining methodology and conclusions to identify bias and determining if evidence logically supports the conclusion. Students develop an understanding that the advancement of scientific knowledge embraces innovation and requires empirical evidence, repeatable investigations, logical arguments, and critical review in striving for the best possible explanations of the natural world by [5] SG2.1 reviewing and recording results of investigations into the natural world.	Climate change research and communication about climate change science could be addressed, but not necessarily. SA2 is particularly timely with respect to climate science and evidence of climate change.
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		No
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		No

forecasting weather days to weeks into the future.		
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.		No
6. HUMAN activities ARE IMPACTING THE CLIMATE SYSTEM.		
A. 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.	SD3 Students develop an understanding of cyclic changes controlled by the energy from the sun and by Earth's position and motion in the Solar system by (10) (11) SD3.1 describing causes, effects, preventions, and mitigations of human impact on climate.	Partial. Emphasis on human activities and greenhouse gases may not be covered. Standard emphasizes the solar energy cycle and planetary movements.
B. 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.	SD3 Students develop an understanding of cyclic changes controlled by the energy from the sun and by Earth's position and motion in the Solar system by (10) (11) SD3.1 describing causes, effects, preventions, and mitigations of human impact on climate.	Partial. Emphasis on greenhouse gases and their persistence may not be covered. Standard emphasizes the solar energy cycle and planetary movements.
C. 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.	SD3 Students develop an understanding of cyclic changes controlled by the energy from the sun and by Earth's position and motion in the Solar system by (10) (11) SD3.1 describing causes, effects, preventions, and mitigations of human impact on climate.	Partial. Specific human activities may not be covered. Standard emphasizes the solar energy cycle and planetary movements.
D. Growing evidence shows that changes in many physical and biological systems are linked to human- caused global warming. 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.	The student demonstrates an understanding that all organisms are linked to each other and their physical environments through the transfer and transformation of matter and energy by: [11] SC3.2 analyzing the potential impact of changes (e.g., climate change, habitat loss/gain, cataclysm, human activities) within an ecosystem.	The potential impact of climate change could be covered, but not necessarily.
E. 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.		No

7. CLIMATE CHANGE WILL have CONSEQUENCES FOR THE EARTH SYSTEM AND HUMAN lives.		
A. 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.	*Glacial melt is relevant to Alaska but glacial rebound counteracts sea level rise in some areas. Storm surge is relevant to low-lying areas of Alaska.*	No
B. Climate plays an 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.		No
C. 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.	*Frequency and severity of storms and changes in precipitation patterns are relevant to Alaska.*	No
D. 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.	*Ocean acidification is particularly relevant to Alaska.*	No
E. 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.	*Relevant to Alaska marine and terrestrial ecosystems.*	No
F. 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.	*Changes in Alaskan health are predicted for Alaska as a result of climate change.*	No