State of New Jersey
Department of Education

Unpacked Earth and Space Sciences Core Ideas:
A Compilation of *A Framework for K-12 Science Education* (NRC, 2012) and the 2020 *New Jersey Student Learning Standards for Science*


S112E05814

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Contents

Introduction

Understanding the Performance Expectations (PE) in the 2020 *New Jersey Student Learning Standards for Science* (NJSLS - S) is made easier when one leverages the documents that accompany it.

In an effort to support teachers in developing a clear and accurate understanding of the disciplinary core ideas in Earth and Space Sciences, the New Jersey Department of Education has created this document which compiles information from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (Framework) (NRC, 2012), 2020 New Jersey Student Learning Standards for Science (NJSLS - S) (NJDOE, 2020), and Evidence Statements for the science performance expectations.

This compilation was developed at the request of educators who reported that using all of the documents simultaneously is cumbersome and often confusing.

Educators who have piloted the use of the document make the following recommendations.

a) Take the time to read the essential question and narrative for the Disciplinary Core Ideas. This provides a macro-structure for student learning and a description of how its Component Idea fit together.

b) Read the essential question and overview for each Component Idea. This provides a kindergarten through grade 12 structure for student learning and how the elements fit together.

c) Pay attention to the essential questions throughout the document. These questions provide an organizational structure for student learning.

Accessibility

The New Jersey Department of Education aims to conform to Level AA of the Web Content Accessibility Guidelines (WCAG 2.1). This document links to documents called Evidence Statements. In an effort to describe more specifically what you would see in proficient student performance of the NJSLS-S Performance Expectations (PE), scientists and educators together developed Evidence Statements for every Performance Expectation (PE) in every grade level. The evidence statements provide clear, measurable components that, if met, fully satisfy each PE described within the NGSS. While the current edition of the Evidence Statements do not meet accessibility guidelines, their unique value warrant their inclusion in this document.

Credits

National Research Council. 2012. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

New Jersey Department of Education. 2020. *New Jersey Student Learning Standards for Science*. Trenton, NJ.

ESS1: Earth’s Place in the Universe

Overview of Earth’s Place in the Universe from Kindergarten through Grade 12

What is the universe, and what is Earth’s place in it?

The planet Earth is a tiny part of a vast universe that has developed over a huge expanse of time. The history of the universe, and of the structures and objects within it, can be deciphered using observations of their present condition together with knowledge of physics and chemistry. Similarly, the patterns of motion of the objects in the solar system can be described and predicted on the basis of observations and an understanding of gravity. Comprehension of these patterns can be used to explain many Earth phenomena, such as day and night, seasons, tides, and phases of the moon. Observations of other solar system objects and of Earth itself can be used to determine Earth’s age and the history of large-scale changes in its surface.

ESS1.A: The Universe and Its Stars

What is the universe, and what goes on in stars?

The sun is but one of a vast number of stars in the Milky Way galaxy, which is one of a vast number of galaxies in the universe.

The universe began with a period of extreme and rapid expansion known as the Big Bang, which occurred about 13.7 billion years ago. This theory is supported by the fact that it provides explanation of observations of distant galaxies receding from our own, of the measured composition of stars and nonstellar gases, and of the maps and spectra of the primordial radiation (cosmic microwave background) that still fills the universe.

Nearly all observable matter in the universe is hydrogen or helium, which formed in the first minutes after the Big Bang. Elements other than these remnants of the Big Bang continue to form within the cores of stars. Nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases the energy seen as starlight. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.

Stars’ radiation of visible light and other forms of energy can be measured and studied to develop explanations about the formation, age, and composition of the universe. Stars go through a sequence of developmental stages—they are formed; evolve in size, mass, and brightness; and eventually burn out. Material from earlier stars that exploded as supernovas is recycled to form younger stars and their planetary systems. The sun is a medium-sized star about halfway through its predicted life span of about 10 billion years.

Grade 1:

What are the objects in the sky and how do they seem to move?

Patterns of the motion of the sun, moon, and stars in the sky can be observed, described, and predicted. At night one can see the light coming from many stars with the naked eye, but telescopes make it possible to see many more and to observe them and the moon and planets in greater detail.

Table 1: Performance Expectation for Grade 1

Standard Code	Performance Expectation
1-ESS1-1	**Use observations of the sun, moon, and stars to describe patterns that can be predicted.** *[Clarification Statement: Examples of patterns could include that the sun and moon appear to rise in one part of the sky, move across the sky, and set; and stars other than our sun are visible at night but not during the day.] [Assessment Boundary: Assessment of star patterns is limited to stars being seen at night and not during the day.]* Click here for the Evidence Statement for 1-ESS1-1.

Grade 5:

Why does our Sun look so much brighter than stars in the night sky?

The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth.

Table 2: Performance Expectation for Grade 5

Standard Code	Performance Expectation
5-ESS1-1	**Support an argument that the apparent brightness of the sun and stars is due to their relative distances from the Earth.** *[Assessment Boundary: Assessment is limited to relative distances, not sizes, of stars. Assessment does not include other factors that affect apparent brightness (such as stellar masses, age, and stage).]* Click here for the Evidence Statement for 5-ESS1-1.

Grades 6 through 8:

What do tides and eclipses have in common?

Why do models of solar system and galaxies always show a circular orbit?

Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. The universe began with a period of extreme and rapid expansion known as the Big Bang. Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.

Table 3: Performance Expectations for Grades 6 through 8

Standard Code	Performance Expectation
MS-ESS1-1	**Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.** *[Clarification Statement: Examples of models can be physical, graphical, or conceptual.]*

Standard Code	Performance Expectation
	Click here for the Evidence Statement for MS-ESS1-1.
MS-ESS1-2	**Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.** *[Clarification Statement: Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them. Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as students' school or state).] [Assessment Boundary: Assessment does not include Kepler's Laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth.]* Click here for the Evidence Statement for MS-ESS1-2.

Grades 9 through 12:

What is the universe, and what goes on in stars?

The star called the sun is changing and will burn out over a life span of approximately 10 billion years. The sun is just one of more than 200 billion stars in the Milky Way galaxy, and the Milky Way is just one of hundreds of billions of galaxies in the universe. The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.

Table 4: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-ESS1-1	**Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.** *[Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.] [Assessment Boundary: Assessment does not include details of the atomic and sub-atomic processes involved with the sun's nuclear fusion.]* Click here for the Evidence Statement for HS-ESS1-1.
HS-ESS1-2	**Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.** *[Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of*

Standard Code	Performance Expectation
	electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).] Click here for the Evidence Statement for HS-ESS1-2.
HS-ESS1-3	**Communicate scientific ideas about the way stars, over their life cycle, produce elements.** *[Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] [Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.]* Click here for the Evidence Statement for HS-ESS1-3.

ESS1.B: Earth and the Solar System

Overview of the Earth and the Solar System Kindergarten through Grade 12

What are the predictable patterns caused by Earth's movement in the solar system?

The solar system consists of the sun and a collection of objects of varying sizes and conditions—including planets and their moons—that are held in orbit around the sun by its gravitational pull on them. This system appears to have formed from a disk of dust and gas, drawn together by gravity.

Earth and the moon, sun, and planets have predictable patterns of movement. These patterns, which are explainable by gravitational forces and conservation laws, in turn explain many large-scale phenomena observed on Earth. Planetary motions around the sun can be predicted using Kepler's three empirical laws, which can be explained based on Newton's theory of gravity. These orbits may also change somewhat due to the gravitational effects from, or collisions with, other bodies. Gradual changes in the shape of Earth's orbit around the sun (over hundreds of thousands of years), together with the tilt of the planet's spin axis (or axis of rotation), have altered the intensity and distribution of sunlight falling on Earth. These phenomena cause cycles of climate change, including the relatively recent cycles of ice ages.

Gravity holds Earth in orbit around the sun, and it holds the moon in orbit around Earth. The pulls of gravity from the sun and the moon cause the patterns of ocean tides. The moon's and sun's positions relative to Earth cause lunar and solar eclipses to occur. The moon's monthly orbit around Earth, the relative positions of the sun, the moon, and the observer and the fact that it shines by reflected sunlight explain the observed phases of the moon.

Even though Earth's orbit is very nearly circular, the intensity of sunlight falling on a given location on the planet's surface changes as it orbits around the sun. Earth's spin axis is tilted relative to the plane of its orbit, and the seasons are a result of that tilt. The intensity of sunlight striking Earth's surface is greatest at the equator. Seasonal variations in that intensity are greatest at the poles.

Grade 1:

What objects are in the sky and how do they seem to move?

Seasonal patterns of sunrise and sunset can be observed, described, and predicted.

Table 5: Performance Expectation for Grade 1

Standard Code	Performance Expectation
1-ESS1-2	**Make observations at different times of year to relate the amount of daylight to the time of year.** *[Clarification Statement: Emphasis is on relative comparisons of the amount of daylight in the winter to the amount in the spring or fall.] [Assessment Boundary: Assessment is limited to relative amounts of daylight, not quantifying the hours or time of daylight.]* Click here for the Evidence Statement for 1-ESS1-2.

Grade 5:

Why doesn't the sky look exactly the same every day?

The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily and seasonal changes in the length and direction of shadows; phases of the moon; and different positions of the sun, moon, and stars at different times of the day, month, and year.

Some objects in the solar system can be seen with the naked eye. Planets in the night sky change positions and are not always visible from Earth as they orbit the sun. Stars appear in patterns called constellations, which can be used for navigation and appear to move together across the sky because of Earth's rotation.

Table 6: Performance Expectation for Grade 5

Standard Code	Performance Expectation
5-ESS1-2	**Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.** *[Clarification Statement: Examples of patterns could include the position and motion of Earth with respect to the sun and selected stars that are visible only in particular months.] [Assessment Boundary: Assessment does not include causes of seasons.]* Click here for the Evidence Statement for 5-ESS1-2.

Grades 6 through 8:

What is the solar system, and what is Earth's place in it?

The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. This model of the solar system can explain tides, eclipses of the sun and the moon, and the motion of the planets in the sky relative to the stars. Earth's spin axis is fixed in direction over the short term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

Table 7: Performance Expectations for Grades 6 through 8

Standard Code	Performance Expectation
MS-ESS1-1	**Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.** *[Clarification Statement: Examples of models can be physical, graphical, or conceptual.]* Click here for the Evidence Statement for MS-ESS1-1.
MS-ESS1-2	**Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.** *[Clarification Statement: Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them. Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as students' school or state).] [Assessment Boundary: Assessment does not include Kepler's Laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth.]* Click here for the Evidence Statement for MS-ESS1-2.
MS-ESS1-3	**Analyze and interpret data to determine scale properties of objects in the solar system.** *[Clarification Statement: Emphasis is on the analysis of data from Earth-based instruments, space-based telescopes, and spacecraft to determine similarities and differences among solar system objects. Examples of scale properties include the sizes of an object's layers (such as crust and atmosphere), surface features (such as volcanoes), and orbital radius. Examples of data include statistical information, drawings and photographs, and models.] [Assessment Boundary: Assessment does not include recalling facts about properties of the planets and other solar system bodies.]* Click here for the Evidence Statement for MS-ESS1-3.

Grades 9 through 12:

What are the predictable patterns caused by Earth's movement in the solar system?

Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the orientation of the planet's axis of rotation, both occurring over tens to hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on Earth. These phenomena cause cycles of ice ages and other gradual climate changes.

Table 8: Performance Expectation for Grades 9 through 12

Standard Code	Performance Expectation
HS-ESS1-4	**Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.** *[Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.]* Click here for the Evidence Statement for HS-ESS1-4.

ESS1.C: The History of Planet Earth

Overview of the History of Planet Earth from Kindergarten through Grade 12

How do people reconstruct and date events in Earth's planetary history?

Earth scientists use the structure, sequence, and properties of rocks, sediments, and fossils, as well as the locations of current and past ocean basins, lakes, and rivers, to reconstruct events in Earth's planetary history. For example, rock layers show the sequence of geological events, and the presence and amount of radioactive elements in rocks make it possible to determine their ages.

Analyses of rock formations and the fossil record are used to establish relative ages. In an undisturbed column of rock, the youngest rocks are at the top, and the oldest are at the bottom. Rock layers have sometimes been rearranged by tectonic forces; rearrangements can be seen or inferred, such as from inverted sequences of fossil types. Core samples obtained from drilling reveal that the continents' rocks (some as old as 4 billion years or more) are much older than rocks on the ocean floor (less than 200 million years), where tectonic processes continually generate new rocks and destroy old ones. The rock record reveals that events on Earth can be catastrophic, occurring over hours to years, or gradual, occurring over thousands to millions of years. Records of fossils and other rocks also show past periods of massive extinctions and extensive volcanic activity. Although active geological processes, such as plate tectonics (link to ESS2.B) and erosion, have destroyed or altered most of the very early rock record on Earth, some other objects in the solar system, such as asteroids and meteorites, have changed little over billions of years. Studying these objects can help scientists deduce the solar system's age and history, including the formation of planet Earth. Study of other planets and their moons, many of which exhibit such features as volcanism and meteor impacts similar to those found on Earth, also help illuminate aspects of Earth's history and changes.

The geological time scale organizes Earth's history into the increasingly long time intervals of eras, periods, and epochs. Major historical events include the formation of mountain chains and ocean basins, volcanic activity, the evolution and extinction of living organisms, periods of massive glaciation, and development of watersheds and rivers. Because many individual plant and animal species existed during known time periods (e.g., dinosaurs), the location of certain types of fossils in the rock record can reveal the age of the rocks and help geologists decipher the history of landforms.

Grade 2:

How does land change and what are some things that cause it to change?

Some events on Earth occur in cycles, like day and night, and others have a beginning and an end, like a volcanic eruption. Some events, like an earthquake, happen very quickly; others, such as the formation of the Grand Canyon, occur very slowly, over a time period much longer than one can observe.

Table 9: Performance Expectation for Grade 2

Standard Code	Performance Expectation
2-ESS1-1	**Use information from several sources to provide evidence that Earth events can occur quickly or slowly.** *[Clarification Statement: Examples of events and timescales could include volcanic explosions and earthquakes, which happen quickly and erosion of rocks, which occurs slowly.] [Assessment Boundary: Assessment does not include quantitative measurements of timescales.]* Click here for the Evidence Statement for 2-ESS1-1.

Grade 4:

How do we know that the shape of the land has changed over time?

Earth has changed over time. Understanding how landforms develop, are weathered (broken down into smaller pieces), and erode (get transported elsewhere) can help infer the history of the current landscape. Local, regional, and global patterns of rock formations reveal changes over time due to Earth forces, such as earthquakes. The presence and location of certain fossil types indicate the order in which rock layers were formed. Patterns of tree rings and ice cores from glaciers can help reconstruct Earth's recent climate history.

Table 10: Performance Expectation for Grade 4

Standard Code	Performance Expectation
4-ESS1-1	**Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time.** *[Clarification Statement: Examples of evidence from patterns could include rock layers with marine*

Standard Code	Performance Expectation
	shell fossils above rock layers with plant fossils and no shells, indicating a change from land to water over time; and, a canyon with different rock layers in the walls and a river in the bottom, indicating that over time a river cut through the rock.] [Assessment Boundary: Assessment does not include specific knowledge of the mechanism of rock formation or memorization of specific rock formations and layers. Assessment is limited to relative time.] Click here for the Evidence Statement for 4-ESS1-1.

Grades 6 through 8:

How do people figure out that the Earth and life on Earth have changed through time?

The geological time scale interpreted from rock strata provides a way to organize Earth's history. Major historical events include the formation of mountain chains and ocean basins, the evolution and extinction of particular living organisms, volcanic eruptions, periods of massive glaciation, and development of watersheds and rivers through glaciation and water erosion. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.

Table 11: Performance Expectation for Grades 6 through 8

Standard Code	Performance Expectation
MS-ESS1-4	**Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.** *[Clarification Statement: Emphasis is on how analyses of rock formations and the fossils they contain are used to establish relative ages of major events in Earth's history. Examples of Earth's major events could range from being very recent (such as the last Ice Age or the earliest fossils of homo sapiens) to very old (such as the formation of Earth or the earliest evidence of life). Examples can include the formation of mountain chains and ocean basins, the evolution or extinction of particular living organisms, or significant volcanic eruptions.] [Assessment Boundary: Assessment does not include recalling the names of specific periods or epochs and events within them.]* Click here for the Evidence Statement for MS-ESS1-4.

Grades 9 through 12:

How do people reconstruct and date events in Earth's planetary history?

Radioactive decay lifetimes and isotopic content in rocks provide a way of dating rock formations and thereby fixing the scale of geological time. Continental rocks, which can be older than 4 billion years, are generally much older than rocks on the ocean floor, which are less than 200 million years old. Tectonic processes continually generate new ocean seafloor at ridges and destroy old seafloor at trenches. Although active geological processes, such as plate tectonics (link to ESS2.B) and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.

Table 12: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-ESS1-5	**Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.** *[Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust decreasing with distance away from a central ancient core of the continental plate (a result of past plate interactions).]* Click here for the Evidence Statement for HS-ESS1-5.
HS-ESS1-6	**Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.** *[Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.]* Click here for the Evidence Statement for HS-ESS1-6.

ESS2: Earth's Systems

Overview of Earth's Systems from Kindergarten through Grade 12

How and why is Earth constantly changing?

Earth's surface is a complex and dynamic set of interconnected systems—principally the geosphere, hydrosphere, atmosphere, and biosphere—that interact over a wide range of temporal and spatial scales. All of Earth's processes are the result of energy flowing and matter cycling within and among these systems. For example, the motion of tectonic plates is part of the cycles of convection in Earth's mantle, driven by outflowing heat and the downward pull of gravity, which result in the formation and changes of many features of Earth's land and undersea surface. Weather and climate are shaped by complex interactions involving sunlight, the ocean, the atmosphere, clouds, ice, land, and life forms. Earth's biosphere has changed the makeup of the geosphere, hydrosphere, and atmosphere over geological time; conversely, geological events and conditions have influenced the evolution of life on the planet. Water is essential to the dynamics of most earth systems, and it plays a significant role in shaping Earth's landscape.

ESS2.A: Earth Materials and Systems

Overview of Earth Materials and Systems from Kindergarten through Grade 12

How do Earth's major systems interact?

Earth is a complex system of interacting subsystems: the geosphere, hydrosphere, atmosphere, and biosphere. The geosphere includes a hot and mostly metallic inner core; a mantle of hot, soft, solid rock; and a crust of rock, soil, and sediments. The atmosphere is the envelope of gas surrounding the planet. The hydrosphere is the ice, water vapor, and liquid water in the atmosphere, ocean, lakes, streams, soils, and groundwater. The presence of living organisms of any type defines the biosphere; life can be found in many parts of the geosphere, hydrosphere, and atmosphere. Humans are of course part of the biosphere, and human activities have important impacts on all of Earth's systems.

All Earth processes are the result of energy flowing and matter cycling within and among Earth's systems. This energy originates from the sun and from Earth's interior. Transfers of energy and the movements of matter can cause chemical and physical changes among Earth's materials and living organisms.

Solid rocks, for example, can be formed by the cooling of molten rock, the accumulation and consolidation of sediments, or the alteration of older rocks by heat, pressure, and fluids. These processes occur under different circumstances and produce different types of rock. Physical and chemical interactions among rocks, sediments, water, air, and plants and animals produce soil. In the carbon, water, and nitrogen cycles, materials cycle between living and nonliving forms and among the atmosphere, soil, rocks, and ocean.

Weather and climate are driven by interactions of the geosphere, hydrosphere, and atmosphere, with inputs of energy from the sun. The tectonic and volcanic processes that create and build mountains and plateaus, for example, as well as the weathering and erosion processes that break down these structures and transport the products, all involve interactions among the geosphere, hydrosphere, and atmosphere. The resulting landforms and the habitats they provide affect the biosphere, which in turn modifies these habitats and affects the atmosphere, particularly through imbalances between the carbon capture and oxygen release that occur in photosynthesis, and the carbon release and oxygen capture that occur in respiration and in the burning of fossil fuels to support human activities.

Earth exchanges mass and energy with the rest of the solar system. It gains or loses energy through incoming solar radiation, thermal radiation to space, and gravitational forces exerted by the sun, moon, and planets. Earth gains mass from the impacts of meteoroids and comets and loses mass from the escape of gases into space.

Earth's systems are dynamic; they interact over a wide range of temporal and spatial scales and continually react to changing influences, including human activities. Components of Earth's systems may appear stable, change slowly over long periods of time, or change abruptly, with significant consequences for living organisms. Changes in part of one system can cause further changes to that system or to other systems, often in surprising and complex ways.

Grade 2:

How does land change and what are some things that cause it to change?

Wind and water can change the shape of the land. The resulting landforms, together with the materials on the land, provide homes for living things.

Table 13: Performance Expectation for Grade 2

Standard Code	Performance Expectation
2-ESS2-1	**Compare multiple solutions designed to slow or prevent wind or water from changing the shape of the land.** *[Clarification Statement: Examples of solutions could include different designs of dikes and windbreaks to hold back wind and water, and different designs for using shrubs, grass, and trees to hold back the land.]* Click here for the Evidence Statement for 2-ESS2-1.

Grade 4:

How can water, ice, wind and vegetation change the land?

Rainfall helps shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. Human activities affect Earth's systems and their interactions at its surface.

Table 14: Performance Expectation for Grade 4

Standard Code	Performance Expectation
4-ESS2-1	**Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.** *[Clarification Statement: Examples of variables to test could include angle of slope in the downhill movement of water, amount of vegetation, speed of wind, relative rate of deposition, cycles of freezing and thawing of water, cycles of heating and cooling, and volume of water flow.]* [Assessment Boundary: Assessment is limited to a single form of weathering or erosion.*]* Click here for the Evidence Statement for 4-ESS2-1.

Grade 5:

How much water can be found in different places on Earth?

Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather.

Table 15: Performance Expectation for Grade 5

Standard Code	Performance Expectation
5-ESS2-1	**Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.** *[Clarification Statement: Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.]* *[*Assessment Boundary: Assessment is limited to the interactions of two systems at a time.*]* Click here for the Evidence Statement for 5-ESS2-1.

Grades 6 through 8:

How do the materials in and on Earth's crust change over time?

How does the movement of tectonic plates impact the surface of Earth?

All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms. The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

Table 16: Performance Expectation for Grades 6 through 8

Standard Code	Performance Expectation
MS-ESS2-1	**Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.** *[Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth's materials.]* *[*Assessment Boundary: Assessment does not include the identification and naming of minerals.*]* Click here for the Evidence Statement for MS-ESS2-1.
MS-ESS2-2	**Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.** *[Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice,*

Standard Code	Performance Expectation
	and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.] Click here for the Evidence Statement for MS-ESS2-2.

Grades 9 through 12:

How do Earth's major systems interact?

Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. A deep knowledge of how feedbacks work within and among Earth's systems is still lacking, thus limiting scientists' ability to predict some changes and their impacts.

Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. The top part of the mantle, along with the crust, forms structures known as tectonic plates (link to ESS2.B). Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and the gravitational movement of denser materials toward the interior. The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

Table 17: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-ESS2-1	**Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.** *[Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).]* [Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.*]* Click here for the Evidence Statement for HS-ESS2-1.
HS-ESS2-2	**Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.** *[Clarification*

Standard Code	Performance Expectation
	Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.] Click here for the Evidence Statement for HS-ESS2-2.
HS-ESS2-3	**Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.** *[Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.]* Click here for the Evidence Statement for HS-ESS2-3.
HS-ESS2-4	**Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.** *[Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.]* Click here for the Evidence Statement for HS-ESS2-4.

ESS2.B: Plate Tectonics and Large-Scale System Interactions

Overview of Plate Tectonics and Large-Scale System Interactions from Kindergarten through Grade 12

Why the continents move? What causes earthquakes and volcanoes?

Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a coherent account of its geological history. This theory is supported by multiple evidence streams—for example, the consistent patterns of earthquake locations, evidence of ocean floor spreading over time given by tracking magnetic patterns in undersea rocks and coordinating them with changes to Earth's magnetic axis data, the warping of the land under loads (such as lakes and ice sheets), which show that the solid mantle's rocks can bend and even flow.

The lighter and less dense continents are embedded in heavier and denser upper-mantle rocks, and together they make up the moving tectonic plates of the lithosphere (Earth's solid outer layer, i.e., the crust and upper mantle). Tectonic plates are the top parts of giant convection cells that bring matter from the hot inner mantle up to the cool surface. These movements are driven by the release of energy (from radioactive decay of unstable isotopes within Earth's interior) and by the cooling and gravitational downward motion of the dense material of the plates after subduction (one plate being drawn under another). The plates move across Earth's surface, carrying the continents, creating and destroying ocean basins, producing earthquakes and volcanoes, and forming mountain ranges and plateaus.

Most continental and ocean floor features are the result of geological activity and earthquakes along plate boundaries. The exact patterns depend on whether the plates are being pushed together to create mountains or deep ocean trenches, being pulled apart to form new ocean floor at mid-ocean ridges, or sliding past each other along surface faults. Most distributions of rocks within Earth's crust, including minerals, fossil fuels, and energy resources, are a direct result of the history of plate motions and collisions and the corresponding changes in the configurations of the continents and ocean basins.

This history is still being written. Continents are continually being shaped and reshaped by competing constructive and destructive geological processes. North America, for example, has gradually grown in size over the past 4 billion years through a complex set of interactions with other continents, including the addition of many new crustal segments.

Grade 2:

What are the different kinds of land and bodies of water?

Maps show where things are located. One can map the shapes and kinds of land and water in any area.

Table 18: Performance Expectation for Grade 2

Standard Code	Performance Expectation
2-ESS2-2	**Develop a model to represent the shapes and kinds of land and bodies of water in an area.** *[*Assessment Boundary: Assessment does not include quantitative scaling in models.*]* Click here for the Evidence Statement for 2-ESS2-2.

Grade 4:

What patterns of Earth's features can be determined with the use of maps?

The locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes occur in patterns. Most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans. Major mountain chains form inside continents or near their edges. Maps can help locate the different land and water features areas of Earth.

Table 19: Performance Expectation for Grade 4

Standard Code	Performance Expectation
4-ESS2-2	**Analyze and interpret data from maps to describe patterns of Earth's features.** *[Clarification Statement: Maps can include topographic maps of Earth's land and ocean floor, as well as maps of the locations of mountains, continental boundaries, volcanoes, and earthquakes.]* Click here for the Evidence Statement for 4-ESS2-2.

Grades 6 through 8:

How does the movement of tectonic plates impact the surface of Earth?

Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geological history. Plate movements are responsible for most continental and ocean floor features and for the distribution of most rocks and minerals within Earth's crust. Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart.

Table 20: Performance Expectation for Grades 6 through 8

Standard Code	Performance Expectation
MS-ESS2-3	**Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.** *[Clarification Statement: Examples of data include similarities of rock and fossil types on different continents, the shapes of the continents (including continental shelves), and the locations of ocean structures (such as ridges, fracture zones, and trenches).]* [Assessment Boundary: Paleomagnetic anomalies in oceanic and continental crust are not assessed.*]* Click here for the Evidence Statement for MS-ESS2-3.

Grades 9 through 12:

How and why is Earth constantly changing?

Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. *(ESS2.B Grade 8 Grade Band Expectation)*

The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection.

Table 21: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-ESS2-1	**Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.** *[Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).] [*Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.*]* Click here for the Evidence Statement for HS-ESS2-1.
HS-ESS2-3	**Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.** *[Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.]* Click here for the Evidence Statement for HS-ESS2-3.

ESS2.C: The Role of Water in Earth's Surface Systems

Overview of the Role of Water in Earth's Surface Systems Kindergarten through Grade 12

How do the properties and movements of water shape Earth's surface and affect its systems?

Earth is often called the water planet because of the abundance of liquid water on its surface and because water's unique combination of physical and chemical properties is central to Earth's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy as it changes state; to transmit sunlight; to expand upon freezing; to dissolve and transport many materials; and to lower the viscosities and freezing points of the material when mixed with fluid rocks in the mantle. Each of these properties plays a role in how water affects other Earth systems (e.g., ice expansion contributes to rock erosion, ocean thermal capacity contributes to moderating temperature variations).

Water is found almost everywhere on Earth, from high in the atmosphere (as water vapor and ice crystals) to low in the atmosphere (precipitation, droplets in clouds) to mountain snowcaps and glaciers (solid) to running liquid water on the land, ocean, and underground. Energy from the sun and the force of gravity drive the continual cycling of water among these reservoirs. Sunlight causes evaporation and propels oceanic and atmospheric circulation, which transports water around the globe. Gravity causes precipitation to fall from clouds and water to flow downward on the land through watersheds.

About 97 percent of Earth's water is in the ocean, and most fresh water is contained in glaciers or underground aquifers; only a tiny fraction of Earth's water is found in streams, lakes, and rivers. The relative availability of water is a major factor in distinguishing habitats for different living organisms.

Water participates both in the dissolution and formation of Earth's materials. The downward flow of water, both in liquid and solid form, shapes landscapes through the erosion, transport, and deposition of sediment. Shoreline waves in the ocean and lakes are powerful agents of erosion. Over millions of years, coastlines have moved back and forth over continents by hundreds of kilometers, largely due to the rise and fall of sea level as the climate changed (e.g., ice ages).

Grade 2:

What are the different kinds of bodies of water?

Water is found in the ocean, rivers, lakes, and ponds. Water exists as solid ice and in liquid form. It carries soil and rocks from one place to another and determines the variety of life forms that can live in a particular location.

Table 22: Performance Expectation for Grade 2

Standard Code	Performance Expectation
2-ESS2-3	**Obtain information to identify where water is found on Earth and that it can be solid or liquid.** Click here for the Evidence Statement for 2-ESS2-3.

Grade 5:

How much water can be found in different places on Earth?

Water is found almost everywhere on Earth: as vapor; as fog or clouds in the atmosphere; as rain or snow falling from clouds; as ice, snow, and running water on land and in the ocean; and as groundwater beneath the surface. The downhill movement of water as it flows to the ocean shapes the appearance of the land. Nearly all of Earth's available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere.

Table 23: Performance Expectation for Grade 5

Standard Code	Performance Expectation
5-ESS2-2	**Describe and graph the amounts and percentages of water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.** *[*Assessment Boundary: Assessment is limited to oceans, lakes, rivers, glaciers, ground water, and polar ice caps, and does not include the atmosphere.*]* Click here for the Evidence Statement for 5-ESS2-3.

Grades 6 through 8:

How does water influence weather, circulate in the oceans, and shape Earth's surface?

Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation as well as downhill flows on land. The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. Global movements of water and its changes in form are propelled by sunlight and gravity. Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.

Table 24: Performance Expectations for Grades 6 through 8

Standard Code	Performance Expectation
MS-ESS2-2	**Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.** *[Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.]* Click here for the Evidence Statement for MS-ESS2-2.
MS-ESS2-4	**Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.** *[Clarification Statement: Emphasis is on the ways water changes its state as it moves through the multiple pathways of the hydrologic cycle. Examples of models can be conceptual or physical.]* [Assessment Boundary: A quantitative understanding of the latent heats of vaporization and fusion is not assessed.*]* Click here for the Evidence Statement for MS-ESS2-4.
MS-ESS2-5	**Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.** *[Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).]* [Assessment Boundary: Assessment does

Standard Code	Performance Expectation
	not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.*]* Click here for the Evidence Statement for MS-ESS2-5.
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.** *[Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.]* [Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.*]* Click here for the Evidence Statement for MS-ESS2-6.

Grades 9 to 12:

How do the properties and movements of water shape Earth's surface and affect its systems?

The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting points of rocks.

Table 25: Performance Expectation for Grades 9 through 12

Standard Code	Performance Expectation
HS-ESS2-5	**Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.** *[Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]* Click here for the Evidence Statement for HS-ESS2-5.

ESS2.D: Weather and Climate

Overview of Weather and Climate from Kindergarten through Grade 12

What regulates weather and climate?

Weather, which varies from day to day and seasonally throughout the year, is the condition of the atmosphere at a given place and time. Climate is longer term and location sensitive; it is the range of a region's weather over 1 year or many years, and, because it depends on latitude and geography, it varies from place to place. Weather and climate are shaped by complex interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions can drive changes that occur over multiple time scales—from days, weeks, and months for weather to years, decades, centuries, and beyond—for climate.

The ocean exerts a major influence on weather and climate. It absorbs and stores large amounts of energy from the sun and releases it very slowly; in that way, the ocean moderates and stabilizes global climates. Energy is redistributed globally through ocean currents (e.g., the Gulf Stream) and also through atmospheric circulation (winds). Sunlight heats Earth's surface, which in turn heats the atmosphere. The resulting temperature patterns, together with Earth's rotation and the configuration of continents and oceans, control the large-scale patterns of atmospheric circulation. Winds gain energy and water vapor content as they cross hot ocean regions, which can lead to tropical storms.

The "greenhouse effect" keeps Earth's surface warmer than it would be otherwise. To maintain any average temperature over time, energy inputs from the sun and from radioactive decay in Earth's interior must be balanced by energy loss due to radiation from the upper atmosphere. However, what determines the temperature at which this balance occurs is a complex set of absorption, reflection, transmission, and redistribution processes in the atmosphere and oceans that determine how long energy stays trapped in these systems before being radiated away. Certain gases in the atmosphere (water vapor, carbon dioxide, methane, and nitrous oxides), which absorb and retain energy that radiates from Earth's surface, essentially insulate the planet. Without this phenomenon, Earth's surface would be too cold to be habitable. However, changes in the atmosphere, such as increases in carbon dioxide, can make regions of Earth too hot to be habitable by many species.

Climate changes, which are defined as significant and persistent changes in an area's average or extreme weather conditions, can occur if any of Earth's systems change (e.g., composition of the atmosphere, reflectivity of Earth's surface). Positive feedback loops can amplify the impacts of these effects and trigger relatively abrupt changes in the climate system; negative feedback loops tend to maintain stable climate conditions.

Some climate changes in Earth's history were rapid shifts (caused by events, such as volcanic eruptions and meteoric impacts, that suddenly put a large amount of particulate matter into the atmosphere or by abrupt changes in ocean currents); other climate changes were gradual and longer term—due, for example, to solar output variations, shifts in the tilt of Earth's axis, or atmospheric change due to the rise of plants and other life forms that modified the atmosphere via photosynthesis. Scientists can infer these changes from geological evidence.

Natural factors that cause climate changes over human time scales (tens or hundreds of years) include variations in the sun's energy output, ocean circulation patterns, atmospheric composition, and volcanic activity. (See ESS3.D for a detailed discussion of human activities and global climate change.) When ocean currents change their flow patterns, such as during El Niño Southern Oscillation conditions, some global regions become warmer or wetter and others become colder or drier. Cumulative increases in the atmospheric concentration of carbon dioxide and other greenhouse gases, whether arising from natural sources or human industrial activity (see ESS3.D), increase the capacity of Earth to retain energy. Changes in surface or atmospheric reflectivity change the amount of energy from the sun that enters the planetary system. Icy surfaces, clouds, aerosols, and larger particles in the atmosphere, such as from volcanic ash, reflect sunlight and thereby decrease the amount of solar energy that can enter the weather/climate system. Conversely, dark surfaces (e.g., roads, most buildings) absorb sunlight and thus increase the energy entering the system.

Kindergarten:

What is the weather like today and how is it different from yesterday?

Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time.

Table 26: Performance Expectation for Kindergarten

Standard Code	Performance Expectation
K-ESS2-1	**Use and share observations of local weather conditions to describe patterns over time.** *[Clarification Statement: Examples of qualitative observations could include descriptions of the weather (such as sunny, cloudy, rainy, and warm); examples of quantitative observations could include numbers of sunny, windy, and rainy days in a month. Examples of patterns could include that it is usually cooler in the morning than in the afternoon and the number of sunny days versus cloudy days in different months.]* [Assessment Boundary: Assessment of quantitative observations limited to whole numbers and relative measures such as warmer/cooler.] Click here for the Evidence Statement for K-ESS2-1.

Grade 3:

What is typical weather in different parts of the world and during different times of the year?

How can the impact of weather-related hazards be reduced?

Weather is the minute-by-minute to day-by-day variation of the atmosphere's condition on a local scale. Scientists record the patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. Climate describes the ranges of an area's typical weather conditions and the extent to which those conditions vary over years to centuries.

Table 27: Performance Expectations for Grade 3

Standard Code	Performance Expectation
3-ESS2-1	**Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.** *[Clarification Statement: Examples of data could include average temperature, precipitation, and wind direction.]* *[*Assessment Boundary: Assessment of graphical displays is limited to pictographs and bar graphs. Assessment does not include climate change.*]* Click here for the Evidence Statement for 3-ESS2-1.
3-ESS2-2	**Obtain and combine information to describe climates in different regions of the world.** Click here for the Evidence Statement for 3-ESS2-2.

Grades 6 through 8:

How does water influence weather, circulation of oceans, and climate?

Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. Because these patterns are so complex, weather can be predicted only probabilistically.

The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents. Greenhouse gases in the atmosphere absorb and retain the energy radiated from land and ocean surfaces, thereby regulating Earth's average surface temperature and keeping it habitable.

Table 28: Performance Expectations for grades 6 through 8

Standard Code	Performance Expectation
MS-ESS2-5	**Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.** *[Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).]* *[*Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.*]* Click here for the Evidence Statement for MS-ESS2-5.

Standard Code	Performance Expectation
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.** *[Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.]* [Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.] Click here for the Evidence Statement for MS-ESS2-6.

Grades 9 through 12:

What regulates weather and climate?

The foundation for Earth's global climate system is the electromagnetic radiation from the sun as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems and this energy's re-radiation into space. Climate change can occur when certain parts of Earth's systems are altered. Geological evidence indicates that past climate changes were either sudden changes caused by alterations in the atmosphere; longer term changes (e.g., ice ages) due to variations in solar output, Earth's orbit, or the orientation of its axis; or even more gradual atmospheric changes due to plants and other organisms that captured carbon dioxide and released oxygen. The time scales of these changes varied from a few to millions of years. Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.

Global climate models incorporate scientists' best knowledge of physical and chemical processes and of the interactions of relevant systems. They are tested by their ability to fit past climate variations. Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and the biosphere. Hence the outcomes depend on human behaviors as well as on natural factors that involve complex feedbacks among Earth's systems.

Table 29: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-ESS2-4	**Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.** *[Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.]* [Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.] Click here for the [Evidence Statement for HS-ESS2-4].
HS-ESS2-6	**Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.** *[Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.]* Click here for the [Evidence Statement for HS-ESS2-6].
HS-ESS2-7	**Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.** *[Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples of include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.]* [Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.] Click here for the [Evidence Statement for HS-ESS2-7].

ESS2.E: Biogeology

Overview of Biogeology from Kindergarten through Grade 12

How do living organisms alter Earth's processes and structures?

Evolution, including the emergence and extinction of species, is a natural and ongoing process that is shaped by Earth's dynamic processes. The properties and conditions of Earth and its atmosphere affect the environments and conditions within which life emerged and evolved—for example, the range of frequencies of light that penetrate the atmosphere to Earth's surface. Organisms continually evolve to new and often more complex forms as they adapt to new environments. The evolution and proliferation of living things have changed the makeup of Earth's geosphere, hydrosphere, and atmosphere over geological time. Plants, algae, and microorganisms produced most of the oxygen (i.e., the O_2) in the atmosphere through photosynthesis, and they enabled the formation of fossil fuels and types of sedimentary rocks. Microbes also changed the chemistry of Earth's surface, and they continue to play a critical role in nutrient cycling (e.g., of nitrogen) in most ecosystems.

Organisms ranging from bacteria to human beings are a major driver of the global carbon cycle, and they influence global climate by modifying the chemical makeup of the atmosphere. Greenhouse gases in particular are continually moved through the reservoirs represented by the ocean, land, life, and atmosphere. The abundance of carbon in the atmosphere is reduced through the ocean floor accumulation of marine sediments and the accumulation of plant biomass; atmospheric carbon is increased through such processes as deforestation and the burning of fossil fuels.

As Earth changes, life on Earth adapts and evolves to those changes, so just as life influences other Earth systems, other Earth systems influence life. Life and the planet's nonliving systems can be said to co-evolve.

Kindergarten:

Where do animals live and why do they live there?

Plants and animals (including humans) depend on the land, water, and air to live and grow. They in turn can change their environment (e.g., the shape of land, the flow of water).

Table 30: Performance Expectation for Kindergarten

Standard Code	Performance Expectation
K-ESS2-2	**Construct an argument supported by evidence for how plants and animals (including humans) can change the environment to meet their needs.** *[Clarification Statement: Examples of plants and animals changing their environment could include a squirrel digs in the ground to hide its food and tree roots can break concrete.]* Click her for the Evidence Statement for K-ESS2-2.

Grade 4:

How can water, ice, wind and vegetation change the land?

Living things affect the physical characteristics of their regions (e.g., plants' roots hold soil in place, beaver shelters and human-built dams alter the flow of water, plants' respiration affects the air). Many types of rocks and minerals are formed from the remains of organisms or are altered by their activities.

Table 31: Performance Expectation for Grade 4

Standard Code	Performance Expectation
4-ESS2-1	**Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.** *[Clarification Statement: Examples of variables to test could include angle of slope in the downhill movement of water, amount of vegetation, speed of wind, relative rate of deposition, cycles of freezing and thawing of water, cycles of heating and cooling, and volume of water flow.]* [Assessment Boundary: Assessment is limited to a single form of weathering or erosion.*]* Click her for the Evidence Statement for 4-ESS2-1.

Grades 6 through 8:

There are no Performance Expectations for ESS2.E: Biogeology in this grade band.

Grades 9 through 12:

How do living organisms alter Earth's processes and structures?

Evolution is shaped by Earth's varying geological conditions. Sudden changes in conditions (e.g., meteor impacts, major volcanic eruptions) have caused mass extinctions, but these changes, as well as more gradual ones, have ultimately allowed other life forms to flourish. The evolution and proliferation of living things over geological time have in turn changed the rates of weathering and erosion of land surfaces, altered the composition of Earth's soils and atmosphere, and affected the distribution of water in the hydrosphere.

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

Table 32: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-ESS2-7	**Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.** *[Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples of include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.] [*Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.*]*

Standard Code	Performance Expectation
	Click her for the Evidence Statement for HS-ESS2-7.

ESS3: Earth and Human Activity

Overview of Earth and Human Activity from Kindergarten through Grade 12

How do Earth's surface processes and human activities affect each other?

Earth's surface processes affect and are affected by human activities. Humans depend on all of the planet's systems for a variety of resources, some of which are renewable or replaceable and some of which are not. Natural hazards and other geological events can significantly alter human populations and activities. Human activities, in turn, can contribute to the frequency and intensity of some natural hazards. Indeed, humans have become one of the most significant agents of change in Earth's surface systems. In particular, it has been shown that climate change—which could have large consequences for all of Earth's surface systems, including the biosphere—is driven not only by natural effects but also by human activities. Sustaining the biosphere will require detailed knowledge and modeling of the factors that affect climate, coupled with the responsible management of natural resources.

ESS3.A: Natural Resources

Overview of Natural Resources from Kindergarten through Grade 12

How do humans depend on Earth's resources?

Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources, including air, water, soil, minerals, metals, energy, plants, and animals. Some of these resources are renewable over human lifetimes, and some are nonrenewable (mineral resources and fossil fuels) or irreplaceable if lost (extinct species).

Materials important to modern technological societies are not uniformly distributed across the planet (e.g., oil in the Middle East, gold in California). Most elements exist in Earth's crust at concentrations too low to be extracted, but in some locations—where geological processes have concentrated them—extraction is economically viable. Historically, humans have populated regions that are climatically, hydrologically, and geologically advantageous for fresh water availability, food production via agriculture, commerce, and other aspects of civilization. Resource availability affects geopolitical relationships and can limit development. As the global human population increases and people's demands for better living conditions increase, resources considered readily available in the past, such as land for agriculture or drinkable water, are becoming scarcer and more valued.

All forms of resource extraction and land use have associated economic, social, environmental, and geopolitical costs and risks, as well as benefits. New technologies and regulations can change the balance of these factors—for example, scientific modeling of the long-term environmental impacts of resource use can help identify potential problems and suggest desirable changes in the patterns of use. Much energy production today comes from nonrenewable sources, such as coal and oil. However, advances in related science and technology are reducing the cost of energy from renewable resources, such as sunlight, and some regulations are favoring their use. As a result, future energy supplies are likely to come from a much wider range of sources.

Kindergarten:

Where do animals live and why do they live there?

Living things need water, air, and resources from the land, and they try to live in places that have the things they need. Humans use natural resources for everything they do: for example, they use soil and water to grow food, wood to burn to provide heat or to build shelters, and materials such as iron or copper extracted from Earth to make cooking pans.

Table 33: Performance Expectation for Kindergarten

Standard Code	Performance Expectation
K-ESS3-1	**Use a model to represent the relationship between the needs of different plants and animals (including humans) and the places they live.** *[Clarification Statement: Examples of relationships could include that deer eat buds and leaves, therefore, they usually live in forested areas; and, grasses need sunlight so they often grow in meadows. Plants, animals, and their surroundings make up a system.]* Click her for the K-ESS3-1 Evidence Statements

Grade 4:

How can we reduce the impact on Earth's Life Support System when we use its resources?

All materials, energy, and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not.

Table 34: Performance Expectation for Grade 4

Standard Code	Performance Expectation
4-ESS3-1	**Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.** *[Clarification Statement: Examples of renewable energy resources could include wind energy, water behind dams, and sunlight; non-renewable energy resources are fossil fuels and fissile materials. Examples of environmental effects could include loss of habitat due to dams, loss of habitat due to surface mining, and air pollution from burning of fossil fuels.]* Click here for the 4-ESS3-1 Evidence Statements

Grades 6 through 8:

How is the availability of needed natural resources related to naturally occurring processes?

Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geological processes. Renewable energy resources, and the technologies to exploit them, are being rapidly developed.

Table 35: Performance Expectation for Grades 6 through 8

Standard Code	Performance Expectation
MS-ESS3-1	**Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.** *[Clarification Statement: Emphasis is on how these resources are limited and typically non-renewable, and how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (locations of the burial of organic marine sediments and subsequent geologic traps), metal ores (locations of past volcanic and hydrothermal activity associated with subduction zones), and soil (locations of active weathering and/or deposition of rock).]* Click her for the MS-ESS3-1 Evidence Statements

Grades 9 through 12:

How do Earth's surface processes and human activities affect each other?

Resource availability has guided the development of human society. All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks, as well as benefits. New technologies and regulations can change the balance of these factors.

Table 36: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-ESS3-1	**Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and [changes in] climate change have influenced human activity.** *[Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or*

Standard Code	Performance Expectation
	drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.] Click her for the HS-ESS3-1 Evidence Statements
HS-ESS3-2	**Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.** *[Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]* Click her for the HS-ESS3-2 Evidence Statements

ESS3.B: Natural Hazards

Overview of Natural Hazards from Kindergarten through Grade 12

How do natural hazards affect individuals and societies?

Natural processes can cause sudden or gradual changes to Earth's systems, some of which may adversely affect humans. Through observations and knowledge of historical events, people know where certain of these hazards—such as earthquakes, tsunamis, volcanic eruptions, severe weather, floods, and coastal erosion—are likely to occur. Understanding these kinds of hazards helps us prepare for and respond to them.

While humans cannot eliminate natural hazards, they can take steps to reduce their impacts. For example, loss of life and economic costs have been greatly reduced by improving construction, developing warning systems, identifying and avoiding high-risk locations, and increasing community preparedness and response capability.

Some natural hazards are preceded by geological activities that allow for reliable predictions; others occur suddenly, with no notice, and are not yet predictable. By tracking the upward movement of magma, for example, volcanic eruptions can often be predicted with enough advance warning to allow neighboring regions to be evacuated. Earthquakes, in contrast, occur suddenly; the specific time, day, or year cannot be predicted. However, the history of earthquakes in a region and the mapping of fault lines can help forecast the likelihood of future events. Finally, satellite monitoring of weather patterns, along with measurements from land, sea, and air, usually can identify developing severe weather and lead to its reliable forecast.

Natural hazards and other geological events have shaped the course of human history, sometimes significantly altering the size of human populations or driving human migrations. Natural hazards can be local, regional, or global in origin, and even local events can have distant impacts because of the interconnectedness of human societies and Earth's systems. Human activities can contribute to the frequency and intensity of some natural hazards (e.g., flooding, forest fires), and risks from natural hazards increase as populations—and population densities—increase in vulnerable locations.

Kindergarten:

How do we keep people safe from severe weather?

Some kinds of severe weather are more likely than others in a given region. Weather scientists forecast severe weather so that communities can prepare for and respond to these events.

Table 37: Performance Expectation for Kindergarten

Standard Code	Performance Expectation
K-ESS3-2	**Ask questions to obtain information about the purpose of weather forecasting to prepare for, and respond to, severe weather.** *[Clarification Statement: Emphasis is on local forms of severe weather.]* Click here for the Evidence Statement for K-ESS3-2.

Grade 3:

What is typical weather in different parts of the world and during different times of the year?

How can the impact of weather-related hazards be reduced?

A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts. (Note: This Disciplinary Core Idea is also addressed by 4-ESS3-2.)

Table 38: Performance Expectation for Grade 3

Standard Code	Performance Expectation
3-ESS3-1	**Make a claim about the merit of a design solution that reduces the impacts of climate change and/or a weather-related hazard** *[Clarification Statement: Examples of design solutions to weather-related hazards could include barriers to prevent flooding, wind resistant roofs, and lighting rods.]* Click here for the Evidence Statement for 3-ESS3-1.

Grade 4:

How do we keep people safe from natural hazards?

A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions, severe weather, floods, coastal erosion). Humans cannot eliminate natural hazards but can take steps to reduce their impacts.

Table 39: Performance Expectation for Grade 4

Standard Code	Performance Expectation
4-ESS3-2	**Generate and compare multiple solutions to reduce the impacts of natural Earth processes and climate change have on humans.** *[Clarification Statement: Examples of solutions could include designing an earthquake resistant building and improving monitoring of volcanic activity.]* [Assessment Boundary: Assessment is limited to earthquakes, floods, tsunamis, and volcanic eruptions.] Click here for the Evidence Statement for 4-ESS3-2.

Grades 6 through 8:

How can natural hazards be predicted?

Some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions. Others, such as earthquakes, occur suddenly and with no notice, and thus they are not yet predictable. However, mapping the history of natural hazards in a region, combined with an understanding of related geological forces can help forecast the locations and likelihoods of future events.

Table 40: Performance Expectation for Grades 6 through 8

Standard Code	Performance Expectation
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.** *[Clarification Statement: Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts).]* Click here for the Evidence Statement for MS-ESS3-2.

Grades 9 through 12:

How do natural hazards affect individuals and societies?

Natural hazards and other geological events have shaped the course of human history by destroying buildings and cities, eroding land, changing the course of rivers, and reducing the amount of arable land. These events have significantly altered the sizes of human populations and have driven human migrations. Natural hazards can be local, regional, or global in origin, and their risks increase as populations grow. Human activities can contribute to the frequency and intensity of some natural hazards.

Table 41: Performance Expectation for Grades 9 through 12

Standard Code	Performance Expectation
HS-ESS3-1	**Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.** *[Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]* Click here for the Evidence Statement for HS-ESS3-1.

ESS3C: Human Impacts on Earth Systems

Overview of Human Impacts on Earth Systems Kindergarten through Grade 12

How do humans change the planet?

Recorded history, as well as chemical and geological evidence, indicates that human activities in agriculture, industry, and everyday life have had major impacts on the land, rivers, ocean, and air. Humans affect the quality, availability, and distribution of Earth's water through the modification of streams, lakes, and groundwater. Large areas of land, including such delicate ecosystems as wetlands, forests, and grasslands, are being transformed by human agriculture, mining, and the expansion of settlements and roads. Human activities now cause land erosion and soil movement annually that exceed all natural processes. Air and water pollution caused by human activities affect the condition of the atmosphere and of rivers and lakes, with damaging effects on other species and on human health. The activities of humans have significantly altered the biosphere, changing or destroying natural habitats and causing the extinction of many living species. These changes also affect the viability of agriculture or fisheries to support human populations. Land use patterns for agriculture and ocean use patterns for fishing are affected not only by changes in population and needs but also by changes in climate or local conditions (such as desertification due to overuse or depletion of fish populations by over-extraction).

Thus, humans have become one of the most significant agents of change in the near-surface Earth system. And because all of Earth's subsystems are interconnected, changes in one system can produce unforeseen changes in others.

The activities and advanced technologies that have built and maintained human civilizations clearly have large consequences for the sustainability of these civilizations and the ecosystems with which they interact. As the human population grows and per-capita consumption of natural resources increases to provide a greater percentage of people with more developed lifestyles and greater longevity, so do the human impacts on the planet.

Some negative effects of human activities are reversible with informed and responsible management. For example, communities are doing many things to help protect Earth's resources and environments. They are treating sewage, reducing the amount of materials they use, and reusing and recycling materials. Regulations regarding water and air pollution have greatly reduced acid rain and stream pollution, and international treaties on the use of certain refrigerant gases have halted the growth of the annual ozone hole over Antarctica. Regulation of fishing and the development of marine preserves can help restore and maintain fish populations. In addition, the development of alternative energy sources can reduce the environmental impacts otherwise caused by the use of fossil fuels.

The sustainability of human societies and of the biodiversity that supports them requires responsible management of natural resources not only to reduce existing adverse impacts but also to prevent such impacts to the extent possible. Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.

Kindergarten:

Where do animals live and why do they live there?

Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things—for example, by reducing trash through reuse and recycling.

Table 42: Performance Expectation for Kindergarten

Standard Code	Performance Expectation
K-ESS3-3	**Communicate solutions that will reduce the impact of climate change and humans on the land, water, air, and/or other living things in the local environment.** *[Clarification Statement: Examples of human impact on the land could include cutting trees to produce paper and using resources to produce bottles. Examples of solutions could include reusing paper and recycling cans and bottles.]* Click here for the Evidence Statement forK-ESS2-3.

Grade 5:

How can we reduce the impacts of humans' use of natural resources?

Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. For example, they are treating sewage, reducing the amounts of materials they use, and regulating sources of pollution such as emissions from factories and power plants or the runoff from agricultural activities.

Table 43: Performance Expectation for Grade 5

Standard Code	Performance Expectation
5-ESS3-1	**Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources, environment [, caused the rise in global temperatures] and address climate change issues.** Click here for the 5-ESS3-1 Evidence Statements.

Grades 6 through 8:

How do human activities affect Earth systems?

Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of many other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Table 44: Performance Expectations for Grades 6 through 8

Standard Code	Performance Expectation
MS-ESS3-3	**Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.** *[Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]* Click here for the Evidence Statement for MS-ESS3-3.
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.** *[Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]* Click here for the Evidence Statement for MS-ESS3-4.

Grades 9 through 12:

How do humans change the planet?

The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. Scientists and engineers can make major contributions—for example, by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. When the source of an environmental problem is understood and international agreement can be reached, human activities can be regulated to mitigate global impacts (e.g., acid rain and the ozone hole near Antarctica).

Table 45: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-ESS3-3	**Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.** *[Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.] [*Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.*]* Click here for the Evidence Statement for HS-ESS3-3.
HS-ESS3-4	**Evaluate or refine a technological solution that reduces impacts of human activities on climate change and other natural systems.** *[Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]* Click here for the Evidence Statement for HS-ESS3-4.

ESS3.D: Global Climate Change

Overview of Global Climate Change from Kindergarten through Grade 12

How do people model and predict the effects of human activities on Earth's climate?

Global climate change, shown to be driven by both natural phenomena and by human activities, could have large consequences for all of Earth's surface systems, including the biosphere (see ESS3.C for a general discussion of climate). Humans are now so numerous and resource dependent that their activities affect every part of the environment, from outer space and the stratosphere to the deepest ocean. However, by using science-based predictive models, humans can anticipate long-term change more effectively than ever before and plan accordingly.

Global changes usually happen too slowly for individuals to recognize, but accumulated human knowledge, together with further scientific research, can help people learn more about these challenges and guide their responses. For example, there are historical records of weather conditions and of the times when plants bloom, animals give birth or migrate, and lakes and rivers freeze and thaw. And scientists can deduce long-past climate conditions from such sources as fossils, pollen grains found in sediments, and isotope ratios in samples of ancient materials.

Scientists build mathematical climate models that simulate the underlying physics and chemistry of the many Earth systems and their complex interactions with each other. These computational models summarize the existing evidence, are tested for their ability to match past patterns, and are then used (together with other kinds of computer models) to forecast how the future may be affected by human activities. The impacts of climate change are uneven and may affect some regions, species, or human populations more severely than others.

Climate models are important tools for predicting, for example, when and where new water supplies will be needed, when and which natural resources will become scarce, how weather patterns may change and with what consequences, whether proposed technological concepts for controlling greenhouse gases will work, and how soon people will have to leave low-lying coastal areas if sea levels continue to rise. Meanwhile, important discoveries are being made—for example, about how the biosphere is responding to the climate changes that have already occurred, how the atmosphere is responding to changes in anthropogenic greenhouse gas emissions, and how greenhouse gases move between the ocean and the atmosphere over long periods. Such information, from models and other scientific and engineering efforts, will continue to be essential to planning for humanity's—and the global climate's—future.

It is important to note that although forecasting the consequences of environmental change is crucial to society, it involves so many complex phenomena and uncertainties that predictions, particularly long-term predictions, always have uncertainties. These arise not only from uncertainties in the underlying science but also from uncertainties about behavioral, economic, and political factors that affect human activity and changes in activity in response to recognition of the problem. However, it is clear not only that human activities play a major role in climate change but also that impacts of climate change—for example, increased frequency of severe storms due to ocean warming—have begun to influence human activities. The prospect of future impacts of climate change due to further increases in atmospheric carbon is prompting consideration of how to avoid or restrict such increases.

Grades Kindergarten through Grade 5:

There are no Performance Expectations for ESS3.D in grades Kindergarten through grade 5.

If Earth's global mean temperature continues to rise, the lives of humans and other organisms will be affected in many different ways.

Grades 6 through 8:

How do we know our global climate is changing?

Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

Table 46: Performance Expectation for Grades 6 through 8

Standard Code	Performance Expectation
MS-ESS3-5	**Ask questions to clarify evidence of the factors that have caused [rise in global temperatures] climate change over the past century.** *[Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.]* Click here for the Evidence Statement for MS-ESS3-5.

Grades 9 through 12:

How do humans change the planet?

Global climate models are often used to understand the process of climate change because these changes are complex and can occur slowly over Earth's history. Though the magnitudes of humans' impacts are greater than they have ever been, so too are humans' abilities to model, predict, and manage current and future impacts. Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities, as well as to changes in human activities. Thus science and engineering will be essential both to understanding the possible impacts of global climate change and to informing decisions about how to slow its rate and consequences—for humanity as well as for the rest of the planet.

Table 47: Performance Expectations for Grades 9 through 12

Standard Code	Performance Expectation
HS-ESS3-5	**Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.** *[Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level,*

Standard Code	Performance Expectation
	glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.] Click here for the Evidence Statement for HS-ESS3-5.
HS-ESS3-6	**Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity (i.e., climate change).** *[Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.]* Click here for the Evidence Statement for HS-ESS3-6.