

## Climate Change Unit Framework

### Enduring Understandings (alignment to Essential Principles of Climate Literacy):

#### 1. The Sun is the primary source of energy for Earth's climate system.

a. Sunlight reaching the Earth can heat the land, ocean, and atmosphere. Some of that sunlight is reflected back to space by the surface, clouds, or ice. Much of the sunlight that reaches Earth is absorbed and warms the planet.

b. When Earth emits the same amount of energy as it absorbs, its energy budget is in balance, and its average temperature remains stable.

#### 2. Climate is regulated by complex interactions among components of the Earth system.

a. Earth's climate is influenced by interactions involving the Sun, ocean, atmosphere, clouds, ice, land, and life. Climate varies by region as a result of local differences in these interactions.

b. Covering 70% of Earth's surface, the ocean exerts a major control on climate by dominating Earth's energy and water cycles. It has the capacity to absorb large amounts of solar energy. Heat and water vapor are redistributed globally through density-driven ocean currents and atmospheric circulation. Changes in ocean circulation caused by tectonic movements or large influxes of fresh water from melting polar ice can lead to significant and even abrupt changes in climate, both locally and on global scales.

c. The amount of solar energy absorbed or radiated by Earth is modulated by the atmosphere and depends on its composition. Greenhouse gases— such as water vapor, carbon dioxide, and methane— occur naturally in small amounts and absorb and release heat energy more efficiently than abundant atmospheric gases like nitrogen and oxygen. Small increases in carbon dioxide concentration have a large effect on the climate system.

d. The abundance of greenhouse gases in the atmosphere is controlled by biogeochemical cycles that continually move these components between their ocean, land, life, and atmosphere reservoirs. The abundance of carbon in the atmosphere is reduced through seafloor accumulation of marine sediments and accumulation of plant biomass and is increased through deforestation and the burning of fossil fuels as well as through other processes.

e. Airborne particulates, called "aerosols," have a complex effect on Earth's energy balance: they can cause both cooling, by reflecting incoming sunlight back out to space, and warming, by absorbing and releasing heat energy in the atmosphere. Small solid and liquid particles can be lofted into the atmosphere through a variety of natural and manmade processes, including volcanic eruptions, sea spray, forest fires, and emissions generated through human activities.

f. The interconnectedness of Earth's systems means that a significant change in any one component of the climate system can influence the equilibrium of the entire Earth system. Positive feedback loops can amplify these effects and trigger abrupt changes in the climate system. These complex interactions may result in climate change that is more rapid and on a larger scale than projected by current climate models.

### **3. Life on Earth depends on, is shaped by, and affects climate.**

a. Individual organisms survive within specific ranges of temperature, precipitation, humidity, and sunlight. Organisms exposed to climate conditions outside their normal range must adapt or migrate, or they will perish.

b. The presence of small amounts of heat-trapping greenhouse gases in the atmosphere warms Earth's surface, resulting in a planet that sustains liquid water and life.

c. Changes in climate conditions can affect the health and function of ecosystems and the survival of entire species. The distribution patterns of fossils show evidence of gradual as well as abrupt extinctions related to climate change in the past.

### **4. Climate varies over space and time through both natural and man-made processes.**

a. Climate is determined by the long-term pattern of temperature and precipitation averages and extremes at a location. Climate descriptions can refer to areas that are local, regional, or global in extent. Climate can be described for different time intervals, such as decades, years, seasons, months, or specific dates of the year.

b. Climate is not the same thing as weather. Weather is the minute-by-minute variable condition of the atmosphere on a local scale. Climate is a conceptual description of an area's average weather conditions and the extent to which those conditions vary over long time intervals.

d. Scientific observations indicate that global climate has changed in the past, is changing now, and will change in the future. The magnitude and direction of this change is not the same at all locations on Earth.

e. Based on evidence from tree rings, other natural records, and scientific observations made around the world, Earth's average temperature is now warmer than it has been for at least the past 1,300 years. Average temperatures have increased markedly in the past 50 years, especially in the North Polar Region.

f. Natural processes driving Earth's long-term climate variability do not explain the rapid climate change observed in recent decades. The only explanation that is consistent with all available evidence is that human impacts are playing an increasing role in climate change. Future changes in climate may be rapid compared to historical changes.

## **5. Our understanding of the climate system is improved through observations, theoretical studies, and modeling.**

- a. The components and processes of Earth's climate system are subject to the same physical laws as the rest of the Universe. Therefore, the behavior of the climate system can be understood and predicted through careful, systematic study.
- b. Environmental observations are the foundation for understanding the climate system. From the bottom of the ocean to the surface of the Sun, instruments on weather stations, buoys, satellites, and other platforms collect climate data. To learn about past climates, scientists use natural records, such as tree rings, ice cores, and sedimentary layers. Historical observations, such as native knowledge and personal journals, also document past climate change.
- c. Observations, experiments, and theory are used to construct and refine computer models that represent the climate system and make predictions about its future behavior. Results from these models lead to better understanding of the linkages between the atmosphere-ocean system and climate conditions and inspire more observations and experiments. Over time, this iterative process will result in more reliable projections of future climate conditions.
- d. Our understanding of climate differs in important ways from our understanding of weather. Climate scientists' ability to predict climate patterns months, years, or decades into the future is constrained by different limitations than those faced by meteorologists in forecasting weather days to weeks into the future.

## **6. Human activities are impacting the climate system.**

- a. The overwhelming consensus of scientific studies on climate indicates that most of the observed increase in global average temperatures since the latter part of the 20th century is very likely due to human activities, primarily from increases in greenhouse gas concentrations resulting from the burning of fossil fuels.
- b. Emissions from the widespread burning of fossil fuels since the start of the Industrial Revolution have increased the concentration of greenhouse gases in the atmosphere. Because these gases can remain in the atmosphere for hundreds of years before being removed by natural processes, their warming influence is projected to persist into the next century.
- c. Human activities have affected the land, oceans, and atmosphere, and these changes have altered global climate patterns. Burning fossil fuels, releasing chemicals into the atmosphere, reducing the amount of forest cover, and rapid expansion of farming, development, and industrial activities are releasing carbon dioxide into the atmosphere and changing the balance of the climate system.

d. Growing evidence shows that changes in many physical and biological systems are linked to human caused global warming. Some changes resulting from human activities have decreased the capacity of the environment to support various species and have substantially reduced ecosystem biodiversity and ecological resilience.

### **7. Climate change will have consequences for the Earth system and human lives.**

a. Melting of ice sheets and glaciers, combined with the thermal expansion of seawater as the oceans warm, is causing sea level to rise. Seawater is beginning to move onto low-lying land, contaminating coastal fresh water sources and gradually submerging coastal facilities and barrier islands. Sea-level rise increases the risk of damage to homes and buildings from storm surges such as those that accompany hurricanes.

e. Ecosystems on land and in the ocean have been and will continue to be disturbed by climate change. Animals, plants, bacteria, and viruses will migrate to new areas with favorable climate conditions. Infectious diseases and certain species will be able to invade areas that they did not previously inhabit.

### **Enduring Understandings (alignment to AAAS Benchmarks):**

#### **Weather and climate involve the transfer of energy in and out of the atmosphere.**

- Climates have sometimes changed abruptly in the past as a result of volcanic eruptions or impacts of huge rocks from space. (AAAS 4B/M6)
- Water evaporates from the surface of the earth, rises and cools, condenses into rain or snow, and falls again to the surface. The water falling on land collects in rivers and lakes, soil, and porous layers of rock, and much of it flows back into the oceans. The cycling of water in and out of the atmosphere is a significant aspect of the weather patterns on Earth. (AAAS 4B/M7)
- Thermal energy is transferred through and between materials in three ways: Conduction, or the collisions of atoms within the material; Convection, or the movement of air, water, or other fluids; and Radiation, or the waves of electromagnetic energy that include light, infrared, and other wavelengths, that can be transformed back into thermal energy when the electromagnetic waves strike another material. (AAAS 4E/M3)

#### **Solar radiation heats the landmasses, oceans, and air.**

- Thermal energy carried by ocean currents has a strong influence on climates around the world. Areas with oceans upwind tend to have more moderate temperatures than they would if they were farther inland but at the same latitude because water in the oceans can hold a large amount of thermal energy. (AAAS 4B/M9)
- The number of hours of daylight and the intensity of the sunlight both vary in a predictable pattern that depends on how far north or south of the equator the place is.

This variation explains why temperatures vary over the course of the year and at different locations. (AAAS 4B/M13)

- Light and other electromagnetic waves can warm objects. How much an object's temperature increases depends on how intense the light striking its surface is, how long the light shines on the object, and how much of the light is absorbed. (AAAS 4E/M6)

### **Energy transfer from the sun and near the Earth's surface determines global climate.**

- Water evaporates from the surface of the earth, rises and cools, condenses into rain or snow, and falls again to the surface. The water falling on land collects in rivers and lakes, soil, and porous layers of rock, and much of it flows back into the oceans. The cycling of water in and out of the atmosphere is a significant aspect of the weather patterns on Earth. (AAAS 4B/M7)
- The temperature of a place on the earth's surface tends to rise and fall in a somewhat predictable pattern every day and over the course of a year. The pattern of temperature changes observed in a place tends to vary depending on how far north or south of the equator the place is, how near to oceans it is, and how high above sea level it is. (AAAS 4B/M12)
- The earth has a variety of climates, defined by average temperature, precipitation, humidity, air pressure, and wind, over time in a particular place. Climate change is not the same everywhere. (AAAS 4B/M14)

### **Human activities have changed the earth's land, oceans, and atmosphere.**

- Human activities such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming, have changed the earth's lands, oceans, and atmosphere. Some of these changes have decreased the capacity of the environment to support some life forms. Climate change is related to energy use. People affect climate in ways they may not like. (AAAS 4C/M7)
- Interactions between components of the Earth's climate system result in changes to the system and produce emergent phenomena unique to the system. Human beings are an integral part of Earth's climate system. Human activities such as fossil fuel burning or deforestation can affect climate and alter the equilibrium of the climate system. (AAAS CL 4H).
- Although climate change can be caused by human activities, it also affects human society in many ways, including agricultural disruption, sea level rise, pests and disease vectors, storms, foods and droughts.
- The Earth system has survived extreme and rapid climate changes, but modern civilization may not be able to.

### **Scientific Inquiry**

- Scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence (AAAS 1B/1)

- Accurate record-keeping, openness, and replication are essential for maintaining an investigator's credibility with other scientists and society (AAAS 1C/7)

### **Essential Questions:**

- What is climate? How does it differ from weather?
- What are current climate conditions dependent on?
- How has climate changed in the past?
- What natural and anthropogenic factors cause climate change?
- Is our climate changing? How are extreme events, such as droughts, floods, wildfires, heat waves, and hurricanes related to climate variability and change?
- What evidence do we have that global climate change has occurred?
- What can we do to reduce our carbon imprint on the environment?
- What contributes to climate change in the United States?
- What contributes to climate change in the world?
- How has climate changed over time on our planet?

### **Topical understandings for this unit (Are specific to the unit topic. Involve generalizations derived from the specific content knowledge and skills of the unit):**

The earth has a variety of climatic patterns, which consist of different conditions of temperature, precipitation, humidity, wind, air pressure, and other atmospheric phenomena. These patterns result from an interplay of many factors. The basic energy source is the heating of land, ocean, and air by solar radiation. Transfer of heat energy at the interfaces of the atmosphere with the land and oceans produces layers at different temperatures in both the air and the oceans. These layers rise or sink or mix, giving rise to winds and ocean currents that carry heat energy between warm and cool regions. The earth's rotation curves the flow of winds and ocean currents, which are further deflected by the shape of the land.

Climate is understood as the atmospheric conditions (i.e., weather variables) averaged over a long period of time (season, year, or longer) and over a large area (region, continent, or larger).

The cycling of water in and out of the atmosphere plays an important part in determining climatic patterns—evaporating from the surface, rising and cooling, condensing into clouds and then into snow or rain, and falling again to the surface, where it collects in rivers, lakes, and porous layers of rock. There are also large areas on the earth's surface covered by thick ice (such as Antarctica), which interacts with the atmosphere and oceans in affecting worldwide variations in climate.

The earth's climates have changed radically and they are expected to continue changing, owing mostly to the effects of geological shifts such as the advance or retreat of glaciers over centuries of time or a series of huge volcanic eruptions in a short time. But even some relatively minor changes of atmospheric content or of ocean temperature, if sustained long enough, can have widespread effects on climate.

Gases in the atmosphere, such as carbon dioxide and water vapor, temporarily trap infrared radiation from the warmed surface of Earth. The additional warmth in the atmosphere created by the greenhouse effect allows liquid water and other life-supporting processes to exist on much of Earth's surface.

Water vapor, carbon dioxide (CO<sub>2</sub>), and other greenhouse gases act to warm Earth's atmosphere by absorbing, and trapping, some of the outgoing radiation from the Earth and reradiating some of this energy back to the surface. The amount, or concentration, of CO<sub>2</sub> gas in the atmosphere has risen more than 30% since widespread fossil-fuel use began with the start of the industrial revolution in the late 1700s. CO<sub>2</sub> concentration in the atmosphere is now at its highest point in more than 600,000 years.

Climate models are computer-based tools used to make projections about future climate and interpret the causes of past changes. They take into account many factors in the climate system, such as greenhouse gases, ocean circulation, and clouds. We gain understanding of climate and how it has changed over time from observational data from weather stations, buoys, satellites, radars, ice and ocean sediment cores, tree rings, cave deposits, native knowledge, and other sources. Observations, experiments, and theory used to construct and refine computer models and develop scientific explanations lead to better understanding of the linkages between the atmosphere-ocean system and how it relates to the overall climate system's behavior. As a result, more reliable projections of future climate changes will develop over time.

The preponderance of scientific evidence indicates that the observed increase in global average temperatures since the latter part of the 20th century is very likely due to documented increases in human-induced greenhouse gas concentrations, primarily from the burning of fossil fuels.

Slowing or reversing human impact on climate change trends might be accomplished by combining short-term strategies -- such as conservation, more efficient use of resources, and the switch from carbon-intensive energy to renewable sources -- with long-term investments in technology research and implementation, and by adopting sustainable development strategies, such as building alternative energy infrastructure and a "green" economy.

### **What key knowledge and skills will students acquire as a result of this unit?**

- Students will understand how climate is different from weather.
- Students will understand that increases in greenhouse gases promote warming and is related to climate change.
- Students will understand how carbon cycles in the biosphere, geosphere, and hydrosphere.

- Students will understand key processes involved with planetary energy balance including albedo, and surface and atmospheric absorption and reflection.
- Students will understand how climate proxy data is used to interpret long-term climate patterns.
- Students will calculate their personal carbon footprint and compare it to average carbon footprints from other countries.
- Students will articulate ways to decrease their own personal carbon emissions.
- Students will understand that scientific evidence indicates human activities are impacting the climate system.

### **ACCEPTABLE EVIDENCE**

**What evidence will show that students understand? (e.g., tests, quizzes, prompts, work samples, observations)**

- Pretest and posttest assessment of global climate change concepts aligned to objectives described above.
- Completion of Climate Change analysis activities.

**Performance Tasks: Through what authentic performance task will students demonstrate understanding?**

- Analyzing of weather data sets and climate data sets.
- Completion of atmospheric gases modeling activity.
- Completion of investigative albedo laboratory.
- Completion of investigative greenhouse effect laboratory.
- Completion of spatial learning activity to determine how latitude, elevation, proximity to bodies of water, and mountain ranges affect a location's climate.
- Completion of paleoclimate reconstruction laboratory to interpret long-term climate patterns and understand annual sediment deposition in lake varves and how it relates to weather and climate patterns.
- Completion of Web-based geologic timeline activity to understand that long term climate patterns provide evidence for fluctuating CO<sub>2</sub> concentrations.
- Completion of carbon calculator activity to determine carbon footprint, examine personal and household habits that produce the most CO<sub>2</sub>, and identify lifestyle changes to reduce one's footprint.
- Completion of spatial learning activity to understand that climate warming has caused changes in landscape features such as glaciers and organisms' habitats.
- Spatial learning activity to analyze the effects of a 2 meter rise in sea level on the existing landscape to understand that climate change will continue to affect our planet into the future.



**By what criteria will student products and performances be evaluated?**

Embedded assessments in all curriculum materials.

**Eligible Content (Pennsylvania Standards)**

**S8.A.1.2.4** Explain society's standard of living in terms of technological advancements and their impact on agriculture. (e.g., transportation, processing production, storage)

**S8.A.1.3.2** Uses evidence, observations or explanations to make inferences about change in systems over time (e.g., carrying capacity, succession, population dynamics, loss of mass in chemical reactions, indicator fossils in geologic time scale) and the variables affecting these changes.

**S8.A.3.2.2** Describe how engineers use models to develop new and improved technologies to solve problems.

**S8.D.2.1.2** Identify how global patterns of atmospheric movement influence regional weather and climate.

**S8.B.3.1.1** Explain the flow of energy through an ecosystem (e.g., food chains, food webs)

**S8.B.3.2.3** Describe the response of organisms to environmental changes (e.g., changes in climate, hibernation, migration, coloration) and how those changes affect survival.

**S8.B.3.3.2** Explain how renewable and nonrenewable resources provide for human needs (i.e. energy, food, water, clothing, and shelter).

**S8.B.3.3.1** Explain how human activities may affect local, regional, and global environments.

**S8.C.2.1.2** Explain how heat is transferred from one place to another through convection, conduction, or radiation.

**3.3.8.A5:**

Explain how the curvature of the earth contributes to climate.

**3.3.8.A6:**

Explain changes in earth systems in terms of energy transformation and transport.

Explain how satellite images, models, and maps are used to identify Earth's resources.

**EE 4.3.7 B. Environmental Health** - Describe how human actions affect the health of the environment.

**EE 4.6.7 A. Ecosystems and Their Interactions** - Explain the flows of energy and matter from organism to organism within an ecosystem.

**EE 4.8.7 B. Humans and the Environment** - Explain how people use natural resources.