

HS-ESS2-4

Students who demonstrate understanding can:

- 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.]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).

- Use a model to provide mechanistic accounts of phenomena.

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science arguments are strengthened by multiple lines of evidence supporting a single explanation.

Disciplinary Core Ideas

ESS1.B: Earth and the Solar System

- Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (*secondary*)

ESS2.A: Earth Materials and System

- 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.

ESS2.D: Weather and Climate

- The foundation for Earth's global climate systems 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.

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Observable features of the student performance by the end of the course:	
1	Components of the model: <p>a From the given model, students identify and describe the components of the model relevant for their mechanistic descriptions. Given models include at least one factor that affects the input of energy, at least one factor that affects the output of energy, and at least one factor that affects the storage and redistribution of energy. Factors are derived from the following list:</p> <ul style="list-style-type: none"> i. Changes in Earth's orbit and the orientation of its axis; ii. Changes in the sun's energy output; iii. Configuration of continents resulting from tectonic activity; iv. Ocean circulation; v. Atmospheric composition (including amount of water vapor and CO₂); vi. Atmospheric circulation; vii. Volcanic activity; viii. Glaciation; ix. Changes in extent or type of vegetation cover; and x. Human activities. <p>b From the given model, students identify the relevant different time scales on which the factors operate.</p>
2	Relationships <p>a Students identify and describe the relationships between components of the given model, and organize the factors from the given model into three groups:</p> <ul style="list-style-type: none"> i. Those that affect the input of energy; ii. Those that affect the output of energy; and iii. Those that affect the storage and redistribution of energy <p>b Students describe the relationships between components of the model as either causal or correlational.</p>
3	Connections <p>a Students use the given model to provide a mechanistic account of the relationship between energy flow in Earth's systems and changes in climate, including:</p> <ul style="list-style-type: none"> i. The specific cause and effect relationships between the factors and the effect on energy flow into and out of Earth's systems; and ii. The net effect of all of the competing factors in changing the climate.