HS.ESS-ES Earth's Systems

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Students who demonstrate understanding can:

a. **Apply scientific reasoning to explain how geophysical, geochemical, and geothermal evidence was used to develop the current model of Earth's interior.** [Clarification Statement: Evidence should include drill cores, gravity, seismic waves, and laboratory experiments on Earth materials.]

b. **Use a model of Earth's interior and the mechanisms of thermal convection to explain the cycling of matter and the impact of plate tectonics on Earth's surface.** [Assessment Boundary: Convection mechanisms should include heat from radioactive decay and gravity acting on materials of different densities as the drivers of convection and tectonic activity.]

c. **Analyze the impact of water on the flow of energy and the cycling of matter within and among Earth systems.** [Assessment Boundary: Should explore the unique physical and chemical properties of water, such as the polar nature of the molecule and water's ability to absorb/store/release energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.]

d. **Use Earth system models to explain how Earth's internal and surface processes work together at different spatial and temporal scales to form landscapes and sea floor features.**

e. **Construct an evidence-based claim about how a change to one part of an Earth system creates feedbacks that causes changes in other systems (e.g., coastal dynamics, watersheds and reservoirs, stream flow and erosion rates, changes in ecosystems).**

f. **Use mathematical expressions of phenomena to simulate how temperature, relative humidity, air pressure, and the dew point vary from the windward to the leeward side of a mountain range.** [Clarification Statement: The phenomena include latent heat, adiabatic heating/cooling, absolute/relative humidity, and dew point.]

g. **Use models to analyze data to make claims about how energy from the sun is redistributed throughout the atmosphere.** [Clarification Statement: Unequal heating of the atmosphere results in high and low pressure systems; air moves from areas of high pressure to low pressure; clockwise and counter-clockwise atmospheric circulations develop in response to Earth's rotation (the Coriolis Effect).]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.
- Use models (including mathematical and computational) to generate data to explain and predict phenomena, analyze systems, and solve problems. (b),(d),(g)

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (c)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Use mathematical expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities. (f)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.
- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (e)
- Apply scientific reasoning, theory, and models to link evidence to claims and show why the data are adequate for the explanation or conclusion. (a)

Disciplinary Core Ideas

ESS2.A: Earth Materials and Systems
- Evidence from drill cores, gravity, seismic waves, and laboratory experiments on Earth materials, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of geophysical and geochemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, and a solid mantle and crust. (a)
- 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 increased downward gravitational pull on denser mantle material. (b)
- Earth's systems interact over a wide range of temporal and spatial scales and continually react to changing influences, including those from human activities. Components of Earth's systems may appear stable, change slowly over long periods of time, or change abruptly. Changes in part of one system can cause dynamic feedbacks that can increase or decrease the original changes, further changing that system or other systems in ways that are often surprising and complex. (d),(e)
- Weather is driven by interactions of the geosphere, hydrosphere, and atmosphere. (f),(g)

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

ESS2.C: The Roles of Water in Earth's Surface Processes
- 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/release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (c)

Crosscutting Concepts

Systems and System Models
Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. (a)

Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (d),(e)

Energy and Matter
The total amount of energy and matter in closed systems is conserved. Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (b),(c),(f),(g)

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Connections to other DCIs in this grade-level: **HS.LS-MEOE, HS.LS-IRE, HS.PS-SPM, HS.PS-CR, HS.PS-ER, HS.PS-E, HS.PS-FM, HS.PS-FE, HS.PS-IF**	
Articulation to DCIs across grade-levels: **K.OTE, K.WEA, 2.IOS, 2.ECS, 3.WCI, 4.PSE, 5.ESI, MS.ESS-EIP, MS.ESS-ESP**	
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]	
ELA –	
W.9-10.1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
W.9-10.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
RST.9-10.3	Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
W.11-12.1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
W.11-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
SL.11-12.2	Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.
RST.11-12.3	Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
Mathematics –	
MP.2	Reason abstractly and quantitatively
MP.4	Model with mathematics
MP.5	Use appropriate tools strategically
S.ID	Summarize, represent, and interpret data on a single count or measurement variable; Summarize, represent, and interpret data on two categorical and quantitative variables
S.IC	Make inferences and justify conclusions from sample surveys, experiments, and observational studies