HS.ESS-CC Climate Change

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Students who demonstrate understanding can:

a. Evaluate and communicate the climate changes that can occur when certain components of the climate system are altered. [Clarification Statement: For example, evaluate variations in incoming solar radiation as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems.]

b. Construct a scientific argument showing that changes to any one of many different Earth and Solar System processes can affect global and regional climates. [Clarification Statement: Examples of these processes include the sun's energy output, Earth's orbit and axis orientation, tectonic events, ocean circulation, volcanic activity, glacial activity, the biosphere, and human activities.] [Assessment Boundary: Use evidence from the geologic record only.]

c. Analyze geologic evidence that past climate changes have occurred over a wide range of time scales. [Clarification Statement: Examples of evidence are ice core data, the fossil record, sea level fluctuations, glacial features.]

d. Engage in critical reading of scientific literature about causes of climate change over 10s-100s of years, 10s-100s of thousands of years, or 10s-100s of millions of years. [Clarification Statement: Examples of causes are changes in solar output, ocean circulation, volcanic activity (10s-100s of years); changes to Earth's orbit and the orientation of its axis (10s-100s of thousands of years); or long-term changes in atmospheric composition (10s-100s of millions of years).]

e. Use global climate models in combination with other geologic data to predict and explain how human activities and natural phenomena affect climate, providing the scientific basis for planning for humanity's future needs. [Clarification Statement: For example, use global climate models together with topographic maps to investigate effects of sea level change or combine global climate models with precipitation maps to investigate locations where new water supplies will be needed.]

f. Apply scientific knowledge to investigate how humans may predict and modify their impacts on future global climate systems (e.g., investigating the feasibility of geoengineering design solutions to global temperature changes).

g. Use models of the flow of energy between the sun and Earth's atmosphere and surface to explain how different wavelengths of energy are absorbed and retained by various greenhouse gases in Earth's atmosphere, thereby affecting Earth's radiative balance. [Clarification Statement: Students will work with absorption spectra of different Earth materials.]

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 multiple types of models to represent and explain phenomena, and move flexibly between model types based on merits and limitations. (g)
- Use models (including mathematical and computational) to generate data to explain and predict phenomena, analyze systems, and solve problems. (e)

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)

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.

- Apply scientific reasoning, theory, and models to link evidence to claims and show why the data are adequate for the explanation or conclusion. (f)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (b)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (a),(d)

Disciplinary Core Ideas

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. Climate change can occur when certain parts of these systems are altered. (a)
- 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. (b),(c),(d)
- Geologic 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 graduate 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 (link to ESS3.D). (b),(c),(d)
- 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. Global climate models incorporate scientists' best knowledge of the physical and chemical processes and of the interactions of relevant systems. They are tested by their ability to fit past climate variations. (e)
- 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 biosphere. Hence the outcomes depend on human behaviors (link to ESS3.D) as well as on natural factors that involve complex feedbacks among Earth's systems (link to ESS3.A). (f)

ESS3.D: Global Climate Change

- Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (g)
- 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. (g)

Crosscutting Concepts

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (e),(g)

Stability and Change

Much of science deals with constructing explanations of how things change and how they remain stable. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Feedback (negative or positive) can stabilize or destabilize a system. Systems can be designed for greater or lesser stability. (a),(b),(c),(d)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (f)

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Connections to other DCIs in this grade-level: **HS.LS-MEOE, HS.LS-IRE, HS.PS-ER, HS.PS-W, HS.PS-E**	
Articulation to DCIs across grade-levels: **K.WEA, K.OTE, 3.WCI, 5.ESI, MS.ESS-WC, MS.ESS-HI**	
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]	
ELA –	
W.9-10.9(b)	Draw evidence from literary or informational texts to support analysis, reflection, and research.
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.
WHST.9-10.1	Write arguments focused on discipline-specific content.
SL.9-10.1.c	Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.
W.11-12.9(b)	Draw evidence from literary or informational texts to support analysis, reflection, and research.
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.
WHST.11-12.1	Write arguments focused on discipline-specific content.
SL.11-12.1.c	Propel conversations by posing and responding to questions that probe reasoning and evidence; ensure a hearing for a full range of positions on a topic or issue; clarify, verify, or challenge ideas and conclusions; and promote divergent and creative perspectives.
Mathematics –	
MP.2	Reason abstractly and quantitatively
MP.3	Construct viable arguments and critique the reasoning of others
MP.4	Model with mathematics
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
F.LE	Construct and compare linear, quadratic, and exponential models and solve problems
S.IC	Make inferences and justify conclusions from sample surveys, experiments, and observational studies