A Closer Look at NGSS
High School Earth and Space Sciences

James Emmerling
Michael Gallagher

Developed for the Introduction to the Next Generation Science Standards, Michigan State University, May 28, 2013
Session Objectives

- Develop an Understanding of NGSS Performance Expectations
- Use one example as a model for learning
Locate 9 - 12 Standards (NGSS Topics)

However, in response to the previous public feedback and direction of the Lead State Partners, the coding structure of individual performance expectations is based on the same DCI arrangement as the Framework. The topic names have been retained in order to allow easy comparisons.

Since many states prefer the topical arrangement, and because the writers want to be transparent about changes made from draft to draft, this topic view is offered to those who prefer to view the NGSS in this form. Due to the fact that the NGSS progress toward end-of-high school core ideas, individual performance expectations may be rearranged in any order within a grade band.
Structure of NGSS

Topic

Performance Expectations

Foundations Boxes
- Science and Engineering Practices
- Disciplinary Core Ideas
- Crosscutting Concepts

Connections Boxes
- DCI within grade
- DCI across grades
- CCSS ELA and Math

Expressed as Performance Expectations (PEs)
- Integrate practices, core ideas, and crosscutting concepts
- Statements of what is to be assessed
- Require demonstration of knowledge-in-use
- NOT instructional strategies
- NOT lesson objectives

State what students should be able to do at the end of instruction
- Organized by Topic and by DCI (See chart)

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How to Read a PE

“NGSS Structure” Supporting document on NGSS page

Inside the NGSS Box – Content Description (NSTA)
http://nstahosted.org/pdfs/ngss/InsideTheNGSSBox.pdf

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How to Read a PE

1. Select one PE. **HS-ESS2-4.** (Weather and Climate)

2. Read the PE, the Clarification Statement, and the Assessment Boundary.

3. Read the applicable DCI in the foundation box.

4. Check Appendix E for DCI progression.

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### How to Read a PE

4. Check Appendix E for DCI progression.

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<td>Energy flows and matter cycles within and among Earth's systems, including the sun and Earth's interior as primary energy sources. Plate tectonics is one result of these processes.</td>
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<td>Water cycles among land, ocean, and atmosphere, and is propelled by sunlight and gravity. Density variations of sea water drive interconnected ocean currents. Water movement causes weathering and erosion, changing landscape features.</td>
<td>The role of radiation from the sun and its interactions with the atmosphere, ocean, and land are the foundation for the global climate system. Global climate models are used to predict future changes, including changes influenced by human behavior and natural factors.</td>
<td>Complex interactions determine local weather patterns and influence climate, including the role of the ocean.</td>
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How to Read a PE

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 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.]

5. Read the associate Practice in the foundation box.

6. Check Appendix F for Practice progression.
### How to Read a PE

6. Check Appendix F for Practice progression.

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<td>Developing and Using Models</td>
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<tr>
<td>A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modeling tools are used to develop questions, predictions and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs.</td>
<td>Modeling in K-2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions.</td>
<td>Modeling in 3-5 builds on K-2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.</td>
<td>Modeling in 6-8 builds on K-5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.</td>
<td>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).</td>
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<td></td>
<td>• Distinguish between a model and the actual object, process, and/or events the model represents.</td>
<td>• Identify limitations of models.</td>
<td>• Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria.</td>
<td>• Design a test of a model to ascertain its reliability.</td>
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<td>• Compare models to identify common features and differences.</td>
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<td>• Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).</td>
<td>• Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events.</td>
<td>• Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution.</td>
<td>• Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.</td>
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<td>• Develop a simple model based on evidence to represent a proposed object or tool.</td>
<td>• Develop a diagram or simple physical prototype to convey a proposed object, tool, or process.</td>
<td>• Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.</td>
<td>• Develop and/or use a model to predict and/or describe phenomena.</td>
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<td>• Develop a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.</td>
<td>• Develop and/or use a model to predict and/or test phenomena, analyze systems, and/or solve problems.</td>
<td>• Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.</td>
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How to Read a PE

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 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.]

7. Read the associated **Crosscutting Concept (CCC)** in the foundation box.

8. Check Appendix G for **Crosscutting Concept (CCC)** progression.
8. Check Appendix G for CCC progression.

2. Cause and Effect: Mechanism and Prediction – Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

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<th>6-8 Crosscutting Statements</th>
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<td>• Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.</td>
<td>• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td>
</tr>
<tr>
<td>• Cause and effect relationships may be used to predict phenomena in natural or designed systems.</td>
<td>• 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.</td>
</tr>
<tr>
<td>• Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.</td>
<td>• Systems can be designed to cause a desired effect.</td>
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<td>• Changes in systems may have various causes that may not have equal effects.</td>
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Strategies for Planning Instruction

- Scaffold the development of understanding expressed in the PE(s).

- Develop a series of learning tasks that blend together various practices, core ideas, and CCC.

- Integrate.

- Consider prior knowledge.
  - Preconception and misconceptions

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Developing a Lesson: Global Climate Change

**Question 1**: What performance expectations are related and can be included in instruction within the lessons/unit? (Cluster PEs)

The following are from the Topic HS.ESS Weather and Climate

**HS-ESS2-4.** Use a model to describe how variations in the flow of energy into and out of Earth systems result in changes in climate.

**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.

The following are from the Topic HS.ESS Earth Systems

**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.

**HS-ESS2-6.** Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

The following are from the Topic HS.ESS Human Impacts

**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.

**HS-ESS3-4.** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*

**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.*

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Developing a Lesson: Global Climate Change

Question 2: What are the performance expectations, clarification statements, and assessment boundaries and how are they related in terms of instructional practices?

The following are from the Topic HS.ESS Weather and Climate

**HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth 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.]

**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, glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]

The following are from the HS.ES Earth Systems

**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 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.]

**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.]

The following are from the HS.ES Human Impact Topics

**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.]

**HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.**
[Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]

**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.**
[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 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.]
Developing a Lesson: Global Climate Change

**Question 3**: What are the Disciplinary Core Idea(s), practices, and crosscutting concepts coded to the performance expectations and how will they drive instruction?

**Disciplinary Core Idea(s)**

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<td>Human activities affect global warming. Decisions to reduce the impact of global warming depend on understanding climate science, engineering capabilities, and social dynamics.</td>
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<td>Global climate models used to predict changes continue to be improved, although discoveries about the global climate system are ongoing and continually needed.</td>
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Question 3: What are the disciplinary core idea(s), Practices, and crosscutting concepts coded to the performance expectations and how will they drive instruction?

Science and Engineering Practices:

| Practice 2: Developing and using models: quantitative models developed in a spreadsheet and computer simulators are tools students use to test mitigation ideas and make predictions. |
| Practice 3: Planning and carrying out investigations - Students will plan and carry out investigations on physical science phenomena, paleoclimatology and predictive modeling. |
| Practice 4: Analyzing and interpreting data - Students will analyze graphical and spatial data using spreadsheets, online analyzers, GIS software and image analysis software. |
| Practice 5: Using mathematics and computational thinking - Students apply mathematics to investigations of Earth systems interactions, global change and predictive modeling. |
| Practice 6: Constructing explanation (for science) and designing solutions (for engineering)- Students construct explanations based on results from investigations on greenhouse gas phenomena, Earth’s climate history and predictive modeling |
| Practice 7: Engaging in argument from evidence: Students reason with evidence to develop sound explanations of past and future climate and climate impact. They weigh tradeoffs of various solutions to the challenges presented by global climate change. |

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Question 3: What are the disciplinary core idea(s), practices, and Crosscutting Concepts coded to the performance expectations and how will they drive instruction?

Crosscutting Concepts

2. Cause and Effect: Mechanism and Prediction – Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

4. Systems and System Models – A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

5. Energy and Matter: Flows, Cycles, and Conservation – Tracking energy and matter flows, into, out of, and within systems helps one understand their system’s behavior.

6. Structure and Function – The way an object is shaped or structured determines many of its properties and functions.

7. Stability and Change – For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.
Developing a Lesson: Global Climate Change

Question 4: What understandings need to be developed for students to be successful in the performance expectation(s)? What content ideas will they need to know and what skills will they need to learn?

Concept to understand:

- Middle school concepts on earth’s climatic systems (i.e., sun’s uneven heating, atmospheric and oceanic circulation, regional climatology)
- How certain gases in the atmosphere trap heat
- How atmospheric concentrations of gases and global temperature have changed over the past century, during the Pleistocene, and in general over the Phanerozoic.
- How to analyze cause and effect, cycles and feedbacks operate among Earth systems, (especially the carbon cycle)
- How human industrial and land use practices impact Earth’s atmosphere.
- Key chemical reactions central to the carbon cycle (e.g., formation of carbonic acid in oceans, release of carbon dioxide in the lime production and combustion of fossil fuels).
- Details of two or three examples of how paleoclimatic research is conducted (e.g., microfossils, ice cores, tree rings)
- How climate models are constructed and used.
- How to analyze prominent examples of global change this is occurring (e.g., melting glaciers, rising sea level, changes in climate and extreme weather, ocean acidification, melting permafrost, biome migration)

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Question 5: What Science and Engineering Practices are appropriate with the instruction of the disciplinary core ideas? (See Appendix F for description of Practices for high school).

Practice 1: Asking questions (for science) and defining problems (for engineering) - Students will make observations of evidence and ask questions on how phenomena impact Earth systems. They will also compare mitigation solutions using a design process.

Practice 2: Developing and using models: quantitative models developed in a spreadsheet and computer simulators are tools students use to test mitigation ideas and make predictions.

Practice 3: Planning and carrying out investigations - Students will plan and carry out investigations on physical science phenomena, paleoclimatology and predictive modeling.

Practice 4: Analyzing and interpreting data - Students will analyze graphical and spatial data using spreadsheets, online analyzers, GIS software and image analysis software.

Practice 5: Using mathematics and computational thinking - Students apply mathematics to investigations of Earth systems interactions, global change and predictive modeling.

Practice 6: Constructing explanation (for science) and designing solutions (for engineering) - Students construct explanations based on results from investigations on greenhouse gas phenomena, Earth’s climate history and predictive modeling.

Practice 7: Engaging in argument from evidence: Students reason with evidence to develop sound explanations of past and future climate and climate impact. They weigh tradeoffs of various solutions to the challenges presented by global climate change.

Practice 8: Obtaining, evaluating, and communicating information - students can analyze informational text and communicate information as well as communicate information gained from observations, data, and investigations.

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Developing a Lesson: Global Climate Change

Question 6: What are the lesson level expectations (learning performances) and how will they build to meet the performance expectations?

- **For Lessons on Patterns and Trends of Global Climate**
  - Plan and carry out investigations in order to generate evidence to support explanations of how certain greenhouse gases trap heat in the atmosphere.
  - Analyze and interpret patterns in data that depict changes in atmospheric parameters (i.e. gas concentration, temperature, precipitation, climatic variability).

- **For Lessons on climate change research using approaches in paleoclimatology and climate modeling**
  - Analyze and interpret paleoclimatic evidence in light of interacting earth systems and constructing an explanation of earth’s climatic history.
  - Use results from climate models to predict a future climate and the impact on Earth systems and humans.

- **For Lessons on monitoring and mitigating global change**
  - Use interpretations of global change research to generate questions that can be addressed through the use of climate models.
  - Support arguments from evidence that evaluate various strategies to mitigate the magnitude and impact of global climate change.

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Question 7: What assessment (formative and summative) will provide evidence of the understanding and/or ability to perform lesson level expectations (learning performances)?

Student production of written explanations, oral arguments, analyses and reports will be used in formative and summative instruments to evaluate these performances:

- For lessons on Patterns and Trends of Global Climate
  - Students demonstrate a detailed and conceptually correct understanding of the mechanisms that cause the greenhouse effect, including how certain gases trap heat in the atmosphere.
  - Students demonstrate an ability hypothesize projected trends of climatic parameters supported by arguments that used the conceptual context of the datasets presented. Datasets could include Mauna Loa carbon dioxide vs. time, Vostok carbon dioxide and temperature vs. time, global temperatures and carbon dioxide emissions.

- For lessons on climate change research using approaches in paleoclimatology and climate modeling
  - Students demonstrate an ability to propose a new paleoclimatic investigation given constraints such as a specific time span. Examples could include selecting a region of ocean floor and applying isotopic techniques on microfossils.
  - Students demonstrate an ability to use a climate change model given a specific goal such as the reduction of global average temperature in a given time frame.

- For lessons on monitoring and mitigating global change
  - Students demonstrate and understanding of connections between Earth systems by proposing research questions related to a global change phenomenon, such as precipitation changes in the Great Lakes region, or impacts on a region’s biome.
  - Students propose and support an impact ranking of several mitigation strategies.

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Question 8: What is the storyline that helps learners apply what they know, build new, sophisticated ideas from observation and evidence, and use information to solve an engineering problem?

The NGSS Earth and Space Science standards in high school are distinct from middle school and involves significant advances in sophistication. In the area of Weather and Climate middle school builds fundamental competencies around weather and Earth’s climatic system. High school builds upon these with a comprehensive focus on global climate change, which is richly complex, highly relevant, integrating topic well suited to the vision for science education put forth by the NGSS. All the scientific practices and crosscutting concepts are necessary for mastery and the problem solving opportunities make use of the design cycle of engineering. The broad interdisciplinary paradigm of Earth System Science came to be through global change research and therefore a unit on global climate change provides the best opportunity to put it to use.

A comprehensive unit in global climate change could be designed into three cycles as demonstrated in Question 6. With this design the students explore Earth’s climatic history through an analysis of the famous and seminal datasets such as the Keeling Curve or Vostok ice core data. In doing so, they develop a fluency of the key patterns and trends that anchor the science of global climate change. They relate patterns in that data to the phenomena and climate forcings within the Earth systems starting with the sun. They develop a sophisticated and accurate understanding of greenhouse gases and the greenhouse effect and relate changes overtime to natural and human induced forcings.

Students develop proficiencies in the central approaches and scientific practice of climate change research. They do this through explorations of several paleoclimatological approaches and understand how they inform climate models. They also use models in the form of equations in spreadsheets and online simulators to test predictions based on the manipulation of climate variables and human actions. Through the manipulation of models they analyze climate forcings, feedbacks and outputs.

Students use their deep and sophisticated understanding of Earth systems, climate history and climate research approaches to analyze ongoing global change that impacts humans and the biosphere. Topics (e.g., melting glaciers, rising sea level, changes in climate and extreme weather, ocean acidification, melting permafrost, biome migration) will be selected and explored using images, spatial and numeric data and scientific reports. Students will propose mitigation strategies and model their impacts in order to evaluate most favorable approaches.

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Question 9: How do the lessons and tasks help students move towards an understanding of the performance expectation(s)?

The lessons and task can be organized into three learning cycles:
1. Patterns and Trends of Global Climate
2. Researching Climate Change
3. Monitoring Global Change

The five key areas of mastering listed in question 2 are attended to within and produce the competencies described by the seven interrelated performance expectations from the topics of Weather and Climate, Earth Systems and Human Impacts.
For More Information

All NGSS official documents are available at

http://www.nextgenscience.org/

NGSS at NSTA

Standards and Supporting Materials Tab

http://www.nsta.org/about/standardsupdate/standards.aspx

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For More Information

- All of today’s session materials will be available at

http://ngss-michigan.org/
Contact Information

James Emmerling – jemmerling@geneseeisd.org

Mike Gallagher – mike.gallagher@oakland.k12.mi.us