Earth-Sun Dynamics 5E

What factors have contributed to climate change in the past and are they contributing to climate change now?

Performance Expectations
HS-ESS2-4

Investigative Phenomenon
The amount of radiation received at 65°N has gone up and down over the last 750,000 years and repeats a pattern about every 100,000 years.

Time
5 days

In this 5E instructional sequence, students are investigating the questions about Earth's position relative to the Sun in the past and present that surfaced during the Driving Question Board launch, such as *How do we know that natural cycles aren't causing climate change today? How has the Earth's position with respect to the Sun changed over time? How does the Earth's changing position with respect to the Sun affect temperatures on Earth?* Students develop and use models to analyze and interpret orbital cycle data to arrive at conclusions about what role Earth's position with respect to the Sun may have played in past climate change events and what role it is having today.

Engage	How has the amount of radiation (sunlight) reaching Earth varied in the past?	Connecting to their earlier questions about how Earth's temperature has varied in the past, students **analyze and interpret** the **total amount of energy** from **solar radiation reaching Earth at 65° N** over the last 750,000 years by **using a mathematical model (graph)**.
Explore	How does Earth's position affect the amount of radiation reaching Earth's surface?	Students **use models** of **Earth's eccentricity, tilt, and direction of tilt** cycles to collect **empirical evidence** in order to determine whether there is a **causal relationship** between **orbital cycles and the amount of solar radiation reaching Earth at 65° N** over the last 750,000 years.
Explain	Did changes in Earth's position cause the patterns of radiation reaching Earth's surface and glacial-interglacial cycles?	Students **use their models to analyze and interpret data in order to make claims** about whether **variations in Earth's position with respect to the Sun (Milankovitch Cycles)** are causing the **total amount of energy** from **solar radiation reaching Earth at 65° N** as well as **glacial-interglacial cycles**.
Elaborate	How well does activity from the Sun correlate with glacial-interglacial cycles?	Students **evaluate evidence** for the **causal relationship** between **changes in the amount of radiation from the Sun** and **the glacial-interglacial cycles**.
Evaluate	How do we know that orbital factors are not causing climate change today?	Students **analyze data about the current orbital factors and solar cycles to explain** the role **cyclic factors** play in **causing** climate change today.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

How has the amount of radiation (sunlight) reaching Earth varied in the past?

Connecting to their earlier questions about how Earth's temperature has varied in the past, students **analyze and interpret** the **total amount of energy** from **solar radiation reaching Earth at 65° N** over the last 750,000 years by **using a mathematical model (graph)**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Pairs	❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Radiation and Temperature During Earth's Past	None	❑ Map of Greenland ❑ Northern Hemisphere Ice Coverage Over 400,000 years ❑ The Rise and Fall of Ice Age Glaciers

Launch

1. Remind students that during the Driving Question Board launch, one category of questions and ideas to investigate that emerged was related to variation in the amount of sunlight / radiation reaching Earth in the past, such as: *How do we know that climate change isn't happening because of natural cycles? How has the amount of radiation (sunlight) reaching Earth varied in the past? Does the amount of radiation (sunlight) that the Sun produces vary over time? Did these natural factors contribute to temperature changes during Earth's past? Do they contribute to global warming today?*

2. Tell students that scientists have been able to collect data from ice cores, tree rings, and ocean

sediments located at high latitudes to determine Earth's temperature as far back as 800,000 years ago at those locations. And they have used similar data along with mathematical models to determine how much solar insolation was reaching Earth over that same time period.

3. Show students the world map to locate Greenland, one of the locations data is collected from, and play the video Northern Hemisphere Ice Coverage Over 400,000 years so they have a visual of how changing temperatures at high latitudes affect ice coverage on Earth.

4. Ask students what they notice about the ice over time. Listen for them to say it increases and decreases in a pattern. Let students know that they are going to have an opportunity to investigate their questions about whether the amount of solar radiation reaching Earth in the past has varied and if it contributes to temperature changes on Earth, as well as the increase and decrease in ice they observed.

5. Help students explain why we are focused on summertime only at 65 N. Remind them that ice sheets, which are key in glacial cycles, form at higher latitudes, and that scientists have discovered a strong correlation between summer insolation at this latitude and glacial-interglacial cycles.

6. Provide students with the handout, *Radiation and Temperature During Earth's Past*, and display the graph. In pairs or table groups, have students use the See-Think-Wonder graphic organizer to make sense of the graph.

Surfacing Student Ideas

1. Have pairs or small groups confer and decide which observation, idea, and question from their See-Think-Wonder they think is most important to share with the class.

2. Use the **Domino Discover** group learning routine, to facilitate students sharing their ideas and questions as a class.

Look & Listen For

Students have background knowledge that can be used to drive the investigation. Listen for the following ideas that students grappled with in middle school:

- I see a pattern of the total amount of insolation reaching Earth at 65° N rising and falling over time.
- The cycles of the total amount of insolation reaching Earth at 65° N changes on a scale of thousands of years.

Classroom Supports

Create a poster or space on a whiteboard for student ideas and questions that surface. Use the title *How has Earth's temperature varied in the past?*

Access for All Learners

- I see a pattern in the glacial and interglacial periods changing over time
- When the insolation is highest, the Earth is in interglacial periods
- The total amount of insolation reaching Earth at 65° N is at its lowest point about every 100 thousand years with some exceptions.
- There are some peaks about half way between the larger peaks.
- While there are general repeating patterns, there are also a lot of irregularities.
- It looks like there is a relationship between insolation and glacial periods
- I think Earth's position with respect to the Sun can impact the total amount of radiation reaching Earth at 65° N.
- I think the amount of energy (radiation) the Sun emits can impact the total amount of radiation reaching Earth at 65° N.
- How does the amount of insolation change?
- How does the amount of insolation affect glacial and interglacial periods? Why aren't they perfectly aligned?

3. Students are likely to have a range of ideas and questions, but are likely to name Earth's position with respect to the Sun and output from the Sun as factors that can impact the total amount of radiation reaching Earth at 65° N. Leverage those ideas and let them know that they will have the opportunity to work with models in order to understand how Earth's changing position and the Sun's output affect the total amount of radiation reaching Earth at 65° N, and then see if what they learn can help them determine whether these factors have contributed to changes in temperature they observed during the unit launch.

4. Before moving on, open a conversation about the word "correlation." Tell students that they are observing a correlation between glacial-interglacial cycles and insolation, because there seems to be a relationship between when they rise and fall. Ask students if they know the difference between "correlation" and "causation." After a discussion about each of these words, ask students what evidence they would need in order to be able to say that there is a causative relationship between these factors.

All students have some background knowledge on the topic of the Earth's orbit, the Sun, and temperatures on Earth, including scientific ideas from Unit 1: Discovering New Worlds and non-scientific ideas from diverse cultural backgrounds. Be sure to provide opportunities for students to articulate those ideas at this point, by documenting ideas that make sense to them. Establishing where student thinking is, allows both learners and the teacher to track how ideas are changed or refined as new information arises.

Routine

This is the first time **Domino Discover** is being used in this unit. This routine is an opportunity to surface students' thinking to the whole class and the teacher. In the Engage phase, it is often used to surface student ideas that can be used to transition the class to the investigation. Refer to the Earth & Space Science Course Guide for support with this routine

Integrating Three Dimensions

This Engage is designed to support students in thinking about **CCC #2 - Cause and Effect**. In this learning sequence, students will need to use empirical evidence to distinguish between causation and correlation, a key component of Cause and Effect at the High School Level. Take time to ensure that students are comfortable using each of those words and the differences between the two.

Explore

How does Earth's position affect the amount of radiation reaching Earth's surface?

Students **use models** of **Earth's eccentricity, tilt, and direction of tilt** cycles to collect **empirical evidence** in order to determine whether there is a **causal relationship** between **orbital cycles and the amount of solar radiation reaching Earth at 65° N** over the last 750,000 years.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Groups of 2-3 Students	❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Orbital Factors Investigation ❑ Making Sense of the Orbital Factors Investigation	❑ Small flashlight ❑ Sphere or globe 6 inches in diameter ❑ markers / pen / pencil	❑ The direction of Earth's tilt with respect to the Sun

Investigation Launch

1. Remind students of their questions regarding how Earth's position with respect to the Sun changes and what impact those changes have on the total amount of radiation reaching Earth at 65° N and average global temperatures throughout Earth's history that they observed during the unit launch.

2. Ask students what changes in Earth's position with respect to the Sun they think could have had or can have on temperatures on Earth.

Look & Listen For

Possible student ideas:

- The distance from the Sun
- The Earth's tilt
- Earth's rotation
- The amount of radiation coming from the Sun

3. Let students know they will now have the opportunity to investigate how some of these factors impact the radiation reaching Earth's surface.

Variation in Earth's Position Investigation

1. Provide students with the handout, *Orbital Factors Investigation.* Have them work in pairs to model each factor of the orbit to see its effect on the Earth. Provide support with figuring out how to model each factor as needed.

2. Confer with students as they work in groups to enact the models and analyze their observations

Conferring Prompts

Confer with students as they work in collaborative groups to make sense of their observations. Suggested conferring questions:

- What are the two extremes of the cycle?
- Do you think these changes impact the total amount of radiation reaching Earth at 65° N?
- Do these changes during the cycle affect the radiation reaching Earth the same everywhere on Earth or does it affect radiation in some places more than others?

Differentiation Point

If a group is struggling with developing any of the models, ask questions to support them in thinking about how to model different points in each of the orbital cycles such as: *How would you model when the Earth is further away from the Sun vs closer to the Sun? How can we observe the difference in how much of the radiation from the Sun (flashlight) is reaching Earth's surface in these different scenarios?* You may also consider pausing the class after about 5-10 minutes for

Access for All Learners

Some students may struggle to make sense of how the changes in Earth's position with respect to the Sun will impact radiation reaching Earth. Be sure to provide all students with access to manipulatives that can be used to model different scenarios.

different groups to share how they are modeling the orbital cycles so groups can adopt ideas from each other.

Whole Class Investigation Summary

1. Once students have completed the investigation, provide students with the handout *Making Sense of the Orbital Factors Investigation*. Have students complete the See-Think-Wonder and answer the analysis question.

2. Ask groups to decide on one important observation, idea and / or question from the See-Think-Wonder or analysis question to share with the whole class, from their discussion.

3. Use the **Domino Discover** group learning routine to surface important observations, inferences, and questions from groups.

Look & Listen For

These student observations and ideas are critical to students' success during the Explain phase:

- Earth's orbit goes through a 100,000 year cycle between nearly circular and more oval like, affecting how close the Earth is to the Sun at different times of a year.
- Our models showed that when Earth is closer to the Sun it receives a higher proportion of radiation from the Sun.
- I think if it receives more radiation it will make the temperature on Earth higher.
- When the Earth is further from the Sun it gets less radiation and that will make it cooler.
- Earth's degree of tilt (axis) with respect to the Sun goes through a 41,000 year cycle between a 22.1 and 24.9 degree tilt, which affects the angle of insolation and concentration of radiation on Earth at different latitudes, including at 65° N.
- The direction of Earth's tilt with respect to the Sun goes through a 26,000 year cycle. At one extreme of the cycle the Earth's northern hemisphere is tilted toward the Sun when the Earth is closest to the Sun. At the other extreme, Earth's northern hemisphere is tilted away from the Sun when the Earth is closest to the Sun.
- I think this has an impact on the angle and concentration of radiation that reaches Earth at different latitudes, including at 65° N.
- How much does each of these changes impact radiation reaching Earth at different latitudes?

Routine

- The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Refer to the Unit 1 Teacher Guide for support with this routine.

- How much does each of these changes impact temperatures on Earth?
- What was happening with Earth's position with respect to the Sun in the past?
- What is happening with Earth's position with respect to the Sun recently?

4. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.

Explain

Did changes in Earth's position cause the patterns of radiation reaching Earth's surface and glacial-interglacial cycles?

Students **use their models to analyze and interpret data in order to make claims** about whether **variations in Earth's position with respect to the Sun (Milankovitch Cycles)** are causing the **total amount of energy** from **solar radiation reaching Earth at 65° N** as well as **glacial-interglacial cycles**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Groups of 2-3 students	❑ Class Consensus Discussion	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Orbital Factors and Glacial Cycles Part 1 ❑ Orbital Factors and Glacial Cycles Part 2 ❑ Summary Task	None	❑ Poster paper ❑ Markers and colored pencils ❑ Class Consensus Discussion Steps ❑ *Sample Class Energy Budget Model* ❑ The Vostok Core and Milankovitch Cycles

Launch

1. Ask a few volunteers to share about the data they explored in the last class. Also ask, *What questions were we trying to answer with the data?* Students explored data related to the Earth's position and how that might change the amount of radiation that reaches Earth at 65°N. Remind students why we are studying areas that are at 65°N.

2. Ask for students to share some of their initial ideas from the Explore about how the Earth's position related to the Sun could affect the amount of radiation that reaches the Earth at 65°N.

3. Direct students to the task by saying: *We used different models to investigate whether changes in the position of the Earth with respect to the Sun could explain changes in the amount of radiation coming to Earth from the Sun. For that, we will apply our models and understanding to different scenarios. Then we will use this understanding to see if they explain real changes in data.*

Explanatory Models

1. Facilitate a class discussion around features of a good explanatory model. Let students know that they will now try to use the data from their observations during the Explore phase as evidence either to support their initial ideas or to revise their thinking.

Features of a good explanatory model
Models are used to represent a system (or parts of a system) under study.
Explanatory models:

- illustrate and/or predict the relationships between systems or between components of a system.
- Utilize scientific vocabulary and labels
- Provide a scientific mechanism for what you are claiming through the model
- Are based on real data

Look & Listen For

Students may generate a range of ideas.

- Models should contain representations of real world objects or ideas
- illustrate and/or predict the relationships between systems or between components of a system.
- Utilize scientific vocabulary and labels

Classroom Supports

Document student ideas and questions surfaced during class discussion, as these will be an important reference for discussions of evidence-based claims later in this unit.

Integrating Three Dimensions

This investigation provides an opportunity to engage with **SEP #2 - Developing and Using Models**. Students may not have an understanding that scientific models are based on real data. Be sure to unpack this enough so that students know the model they create will be based on evidence. This is particularly important, because they will be using data generated from this model to make evidence-based claims.

- Provide a scientific mechanism for what you are claiming through the model

All student ideas can be recorded at this point; some may be ruled out later in the unit.

2. Let students know that they will use and develop models to analyze data about how Earth's orbital factors were changing over specific periods of time. They will then compare their models to a computational model of that data to figure out the role of orbital factors in creating glacial-interglacial cycles.

Developing and Using Models of Orbital Factors During Climatic Changes

1. Provide students with the handout, *Orbital Factors and Glacial Cycles Part 1*. Ask them to complete parts 1 in groups of 2-3.

Implementation Tip

In part 1 of this activity, students are explaining how changes in orbital factors result in different amounts of insolation reaching Earth. The models they are engaging with are scaffolded to increase in complexity throughout the task. In the first example, they are responsible for determining how the orbital factors would influence sunlight in northern hemisphere summers using fully drawn models. In the third example, they have to use data describing the orbital positions to complete the visual model and then analyze the impact on summer.

2. Put students in groups of 3-4, and tell them to take turns sharing ideas from their models and explanations to develop a group model on poster paper. Their group model should explain the mechanism of how Earth's changing position with respect to how the Sun affects the melting and freezing of ice sheets in each of the three timeframes observed in part 1. Use the conferring questions to support students in developing their models.

Conferring Prompts

Suggested conferring questions:
These questions should support and push students' thinking about how they are using their model to provide a mechanistic account of how Earth's changing position with respect to the Sun affects the melting and freezing of ice sheets.

- What is happening to the total amount of radiation reaching Earth?

Integrating Three Dimensions

Students are working toward proficiency in **using a model to provide a mechanistic account of phenomena**, an important element of **SEP #2 - Developing and Using Models** at the HS level. The suggested conferring questions are meant to push students toward clearly illustrating a mechanistic account for the phenomenon depicted by the glacial interglacial graph. Mechanistic accounts will also be an important consideration later, when students evaluate the strength of causal relationships in their claims.

    - How are you representing that on your model?
- What is happening to the total amount of radiation reaching Earth at 65° N?
    - How are you representing that on your model?
- What is happening to the amount of radiation reaching the ice sheets?
    - How does your model help you explain this?
- What impact will changes in radiation you're depicting have on ice sheets?
- What evidence and science concepts support your claim?

3. Tell students that they will now have the opportunity to use a computational model to better observe the correlation between orbital factors and glacial-interglacial cycles.

4. Provide students with the handout *Orbital Factors and Glacial Cycles Part 1*. Have them work in their original groups of 2-3 to complete that section, including the summary questions.

5. Have students turn back to their larger table groups and give them an opportunity to revise their explanatory models.

6. Have groups post their explanatory models around the room.

Class Consensus Discussion

1. Orient the class to the purpose and the format of the **Class Consensus Discussion** group learning routine. You may say something like,

*We have a lot of different ideas circulating in the room right now, and they are in the form of different explanatory models you have developed. It is really important for us to get to some agreement on how we represent what we know about how Earth's varying position with respect to the Sun and how that impacts the total radiation reaching Earth at 65° N and glacial-interglacial cycles, so we have a shared understanding to build on as we move forward. In order to do this, we are going to have a **Class Consensus Discussion**. First, I will select a few different groups to share their ideas and models. Then, we will let each group share their claim and models and discuss what we can agree on as a class.*

2. You may decide to walk students through the entire poster of Class Consensus Discussion steps, or take them through the steps as you facilitate it.

3. Post a piece or two of chart paper in front of the classroom and label it "Class Consensus Ideas: Earth's Position and Changing Ice Sheets." You will be recording student ideas on this paper as they surface during presentations.Select two or three groups' scientific explanations to share with the class. At this

Routine

Class Consensus Discussions are so important for the Explain phase across this unit and the course. It provides an opportunity for groups to share out around their sensemaking and for other groups to list, summarize, and ask questions after each share. This is the first time doing such a discussion in this unit, so focus more on the *steps* and the

point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of how Earth's varying position with respect to the Sun impacts the radiation reaching Earth and glacial-interglacial cycles. The decision about which explanations to share with the class should be based on both the ideas circulating in the classroom *and* the goals of this part of the 5E sequence. Look ahead to the "Take Time for these Key Points" below to help you determine which groups you want to share out, so that those key points are surfaced.

4. While students are presenting, be sure to post the graph of glacial-interglacial cycles for them to reference as they explain their posters.

5. Ask the first group to share their claim. You can do this by:
    - Projecting using a document camera; OR
    - Copying the claims to be shared and passing them out to the class; OR
    - Taking a picture of each model and projecting them as slides.

6. Proceed through the steps in the Consensus Discussion Steps.

Class Consensus Discussion Steps

1. We listen to a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.
7. We agree or disagree (and tell why) with the ideas or offer revision ideas.

7. Before table groups confer, prompt them to consider the strength of the models. Some prompts you might provide are:

What evidence do you have for your model?
What is the mechanism for what you are claiming? What are the science ideas involved?
How confident do you feel about your claims? Why?

process. In future parts of this unit, you will use this format to do more in-depth discussions and consensus building. For now, it's just about establishing a common understanding of the format.

Classroom Supports

Post the steps to the Class Consensus Discussion in the room, as a reference you can return to in future lessons.

Integrating Three Dimensions

The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC #2 - Cause and Effect** explicit for students by elevating and probing for ideas related to the concept that **empirical evidence is required to make claims about specific causes and effects.**

Access for Multilingual Learners

Rather than assigning a list of vocabulary words—a technique that rarely works for learning new vocabulary—this activity allows language learners to learn vocabulary from context,

How would each factor impact energy reaching Earth, considering both input and distribution?

8. Resume the whole class discussion and, as the class agrees on important ideas or clear ways to represent their ideas, add them to the Class Consensus Chart.

9. After all student ideas are captured on the class consensus list, ask the class if they agree, have different ideas, or if they disagree. If students disagree about or are uncertain of ideas, label them with a question mark (?). Having questions at this point is fine and you should expect some to be there.

10. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge. Sometimes, important points may get buried in student talk; use the guidelines below to ensure the class focuses on ideas that will drive the lesson and unit forward.

which may be particularly helpful for **transitioning** language learners, who already have some mastery of language.

Implementation Tip

Tip: We recommend you do NOT just let students read their explanatory model students will be developing aloud. Some classmates will need to see/read the explanatory model students will be developing to be able to follow up. A discussion with no visual component can leave out a number of students.

Take Time for These Key Points

Pause the discussion and ask for clarification, particularly of the following **key points**:

- 130 kya Earth was closer to the Sun and more tilted toward the Sun during the northern hemisphere Summer than it was 150 kya.
    - This would have caused there to be more summer radiation reaching Earth and the concentration of radiation reaching Earth at 65° N to increase.
    - This would have increased temperature at 65° N like we saw during that time frame in the glacial-interglacial cycles, shifting the Earth to an interglacial period.
- Between 130 kya and 113 kya the direction of Earth's tilt changed, so it was a lot further to the Sun during the northern hemisphere Summer. The degree of tilt toward the Sun decreased during the same time period as well. The distance between Earth at different points in its orbit changed very little.
    - This would have caused there to be less total radiation reaching Earth and the concentration of radiation reaching Earth at 65° N to decrease.
    - This would have decreased temperature at 65° N like we saw during that time frame in the glacial-interglacial cycles, shifting the Earth to an glacial period.

- Between 25 kya and 9 kya the degree of earth's tilt toward the Sun increased.
    - This would have caused the concentration of radiation reaching Earth at 65° N to increase.
    - This would have increased temperature at 65° N like we saw during that time frame in the glacial-interglacial cycles, shifting the Earth to an glacial period.

Note: *As the class comes to agreement on these ideas, summarize them on the Class Consensus Model. If there is still some disagreement, add that to the class model or mark it with a question mark (?). Ask the class to offer reasoning for the ideas. The question mark can also mean a student doesn't quite understand all the reasoning. These question marks will be the navigation in the next activity.*

11. Post an additional piece of chart paper in the front of the room and label it "Class Consensus Model: Global Energy Budget"

Note: you will return to this Model throughout the unit to add complexity as students gain further information about energy inputs and outputs on Earth in future 5Es. The goal of this chart will be to construct a global energy budget model including elements from each 5E moving forward.
An example is included in *Sample Class Energy Budget Model*

12. On the "Class Consensus Model: Global Energy Budget," use ideas from the consensus discussion to construct an overall model of the combined impact of orbital factors on the amount of energy reaching Earth. Leave space in this model; the class will be adding impacts of ice caps, oceans, and greenhouse gases to the model over time.

13. Then point out to students that they have not considered whether the output from the Sun could have contributed to the glacial-interglacial cycles. Ask them why it might be important to determine how much the different orbital forcing factors (eccentricity, direction of tilt, and degree of tilt) contributed to the glacial-interglacial cycles and whether output from the Sun contributed to the glacial-interglacial cycles.

Look & Listen For

Possible student ideas:

- It will help us strengthen our claims if we can explain which factors contribute most.
- There are parts of the glacial-interglacial cycles we have not explained, so maybe other factors like the Sun's output can help us.
- It would not be a complete explanation / or model if we do not consider those questions.

14. Students individually complete the *Summary Task*. This can be completed in class or as an exit ticket or for homework.

15. The results of this task can be used to make determinations about which students need more time to circle back to the ideas in this text in the coming parts of the 5E lesson.

Implementation Tip

This summary is really important! It's an opportunity to check in on each student's thinking at this point in the unit, in a few different areas:
1) understanding how they are **using the three dimensions to make sense of a phenomenon**; 2) ideas about how they and their peers are **building knowledge together**; 3) how they think the class consensus discussion went. It's important to get all of this from individual students, so you know these things on a student-by-student basis.

16. Tell students they will now have an opportunity to explore the varying impact of eccentricity, direction of tilt, and degree of tilt as well as the output of radiation from the Sun.

Elaborate

How well does activity from the Sun correlate with glacial-interglacial cycles?

Students **evaluate evidence** for the **causal relationship** between **changes in the amount of radiation from the Sun** and **the glacial-interglacial cycles**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Pairs	None	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Solar Cycles	None	

Launch

1. Remind students that last time they wanted to further investigate another idea they had about variables that influence climate was about the amount of radiation the Sun is emitting. Ask students what data they want to look at in order to collect evidence that will support claims about whether the Sun's total emitted radiation was a factor that contributed to past climate change events. If students have ideas that relate to radiation from the Sun already posted on the Ideas for Investigations chart from the Unit Launch, use those initial ideas to help students think of additional ideas for investigations.

Look & Listen For

Possible student ideas:

- We want to see data that shows us if and how the total amount of radiation emitted by the Sun has changed over time.
- We want to compare this data to temperature changes on Earth
- It would be helpful to see this data as a visual like a graph
- We should look for patterns or cycles and see at what rate the Sun's output of radiation has changed and compare the direction and rate of those changes to the direction and changes in Earth's temperature.

Implementation Tip

This task is an opportunity to continue developing an understanding of the idea that **empirical evidence is needed to distinguish between correlation and causation,** an important high school element of **CCC #2 - Cause and Effect.** A key part of making claims about causality is to consider other variables that could potentially explain a phenomenon. Here students are investigating whether output from the Sun can help to explain solar radiation reaching Earth at 65° N as well as glacial-interglacial cycles.

2. Let them know that the NASA has been investigating this same question and has produced graphs of the amount of radiation the Sun has emitted over time by using isotope proxies in the same way oxygen isotopes were used to infer the Earth's temperature in the past, as well as data collected through instruments since the 1960's.

Making Claims about the Causal Relationship Between the Sun's Total output and Global Temperature Changes

1. Provide students with the handout, *Solar Cycles* Have them work independently or in pairs to analyze and interpret the 2 graphs of the Sun's total irradiance vs average global temperatures over time, and use what they observe to complete the See-Think-Wonder that follows.

Conferring Prompts

Confer with students as they work to analyze and interpret the graph and complete the See-Think-Wonder table.

Suggested conferring questions (these should push students' thinking around establishing relationships, observing patterns, identifying variables, and questioning events):

Access for Multilingual Learners

Writing a well-reasoned argument is a complex task. By providing time for students to think through the reasoning of their argument (in the card sort), **transitioning** language learners got time to work with the requisite language in

- What patterns do you notice in the data? Are there any apparent cycles in the data? What is your empirical evidence?
- What is the time scale of any cycles you're seeing?
- What was happening to the total amount of radiation emitted from the Sun around the time of the climate change event you're investigating?
- Does the direction of the trend in global temperatures seem to indicate that the Sun's total radiation output may have contributed to temperature changes around the time of the climate change event you're investigating?
- Does the scale of time of changes in the Sun's total radiation output vs scale of temperature changes seem to indicate that Sun's total radiation output contributes to temperature changes around the time of the climate change event you're investigating?

preparation for writing. Note that **emerging** English learners may need to do this task with additional support—verbally, in a home language, or some other way.

2. Have students work independently or in pairs to view the images and graphs and respond to the questions. They should end by responding to the question: :
    - Did the Sun's total output contribute to the climate change event you're investigating? What is your evidence and scientific reasoning?

Look & Listen For

Possible student ideas:

- There are cycles that last about 10-11 years; that scale of time does not match the scale of time (10s and 100s of thousand years) during which the glacial-interglacial occurred.
- I think the total amount of radiation from the Sun does impact temperature on Earth because radiation is energy that can heat the Earth.
- At times, increasing sunspot activity is correlated with increasing temperatures, but at other times, they are not correlated
- Orbital factors may contribute more strongly to Earth's temperature than solar activity

Evaluate

How do we know that orbital factors are not causing climate change today?

Students **analyze data about the** **current orbital factors and solar cycles** **to explain** the role **cyclic factors** play in **causing** climate change today.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Individual	❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Revisiting the Performance Task: Earth-Sun Dynamics 5E ❑ The Sun and Current Climate Change - Performance Task Data ❑ Earth-Sun Dynamics Rubric	None	

Return to the Performance Task

1. Remind students that their task is to disprove skeptics who claim that climate change is happening because of natural causes like changing orbital factors or solar cycles.

2. Provide them with the handout *The Sun and Current Climate Change - Performance Task Data.* Students can work in small groups or individually to analyze the data, which they will then use to complete the performance task.

3. Have students work individually to complete the explanation in the *Revisiting the Performance Task:*

Earth-Sun Dynamics 5E.

2. Confer with students while they are working.

Conferring Prompts

Confer with students as they work to develop models and explanations. Prompt students to return to the class wide correlation to causation spectrum checklist questions as they develop and evaluate claims.

Suggested conferring questions:

- What evidence did you generate in this 5E sequence?
- Where did the evidence come from?
- How well does that evidence support the claim?
- What ideas or contradictory evidence weaken the claim?

Revisiting the Temperature Data and Driving Question Board

1. Return to the Tell the Story documents and the Driving Question Board. Ask students to discuss what questions have been answered and what still remains.

2. Conduct a **Domino Discover** to hear from each group

Look & Listen For

Possible student ideas:

- We explained past climate change events on a scale of 10 and 100s of thousands of years, but we have not explained why sun-earth dynamics do not fully explain glacial-interglacial cycles
- We have determined that sun-earth dynamics are not causing the changes in temperature that we are seeing now
- We haven't determined what is causing climate change now

3. Ask students what they think might be causing climate change, based on their prior knowledge. Students are likely to say that they think humans and/or greenhouse gases are likely playing a role. Leverage that prior knowledge to transition into the next 5E.

Standards in Earth-Sun Dynamics 5E

Performance Expectations

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.

In NYS the clarification statement has been edited as follows: Examples of the causes of climate change could include those that differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation, solar output; 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 and plate tectonic.

Aspects of Three-Dimensional Learning

Science and Engineering Practices

Developing and Using Models
- Use a model to provide mechanistic accounts of phenomena. SEP2(5)

Analyzing and Interpreting Data
- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. SEP4(1)

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. ESS1.B(2)

ESS2.A Earth Materials and Systems
- The geologic 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

Crosscutting Concepts

Cause and Effect
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. CCC2(1)

Energy and Matter
- The total amount of energy and matter in closed systems is conserved. CCC5(1)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
	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.A(3) 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. ESS2.D(1) ESS2.E Biogeology ● The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it. ESS2.E(1)	

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Developing and Using Models		*Orbital Factors Investigation* *Making Sense of the Orbital Factors Investigation*	*Orbital Factors and Glacial Cycles Part 1* *Orbital Factors and Glacial Cycles Part 2* *Summary Task*	*Solar Cycles*	*Revisiting the Performance Task: Earth-Sun Dynamics 5E*

	Engage	Explore	Explain	Elaborate	Evaluate
Analyzing and Interpreting Data	*Radiation and Temperature During Earth's Past*	*Orbital Factors Investigation* *Making Sense of the Orbital Factors Investigation*	*Orbital Factors and Glacial Cycles Part 1* *Orbital Factors and Glacial Cycles Part 2* *Summary Task*		*Revisiting the Performance Task: Earth-Sun Dynamics 5E*
ESS1.B Earth and the Solar System		*Orbital Factors Investigation* *Making Sense of the Orbital Factors Investigation*	*Orbital Factors and Glacial Cycles Part 1* *Orbital Factors and Glacial Cycles Part 2* *Summary Task*		*Revisiting the Performance Task: Earth-Sun Dynamics 5E*
ESS2.A Earth Materials and Systems	*Radiation and Temperature During Earth's Past*	*Orbital Factors Investigation* *Making Sense of the Orbital Factors Investigation*	*Orbital Factors and Glacial Cycles Part 1* *Orbital Factors and Glacial Cycles Part 2* *Summary Task*		*Revisiting the Performance Task: Earth-Sun Dynamics 5E*
ESS2.D Weather and Climate	*Radiation and Temperature During Earth's Past*	*Orbital Factors Investigation* *Making Sense of the Orbital Factors Investigation*	*Orbital Factors and Glacial Cycles Part 1* *Orbital Factors and Glacial Cycles Part 2* *Summary Task*		*Revisiting the Performance Task: Earth-Sun Dynamics 5E*
ESS2.E Biogeology				*Solar Cycles*	
Cause and Effect	*Radiation and Temperature During Earth's Past*	*Orbital Factors Investigation* *Making Sense of the Orbital Factors Investigation*	*Orbital Factors and Glacial Cycles Part 1* *Orbital Factors and Glacial Cycles Part 2* *Summary Task*	*Solar Cycles*	*Revisiting the Performance Task: Earth-Sun Dynamics 5E*
Energy and Matter	*Radiation and Temperature During Earth's Past*	*Orbital Factors Investigation* *Making Sense of the Orbital Factors Investigation*	*Orbital Factors and Glacial Cycles Part 1* *Orbital Factors and Glacial Cycles Part 2* *Summary Task*		*Revisiting the Performance Task: Earth-Sun Dynamics 5E*

Common Core State Standards Connections

	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics		MP2 MP3 MP4 MP6	MP2 MP3 MP4 MP6		
ELA/Literacy		WHST.9-10.9	WHST.9-10.9	WHST.9-10.1 WHST.9-10.5 SL.9-10.4	WHST.9-10.1 WHST.9-10.9