

Session 11: Evidence of Sea Level Rise and Climate Change

Overview

Participants examine evidence of the effects of sea level rise on a local and global scale, and engage in an activity that explores the causes of sea level rise, allowing them to make claims as to the causes. They consider additional pieces of evidence, working collaboratively to make evidence-based cause and effect connections. They then use the crosscutting concept of cause and effect to connect the different forms of evidence they are examining, in order to construct some explanations of climate change. Participants explore how scientists determine what the pattern or relationship in their data is, and also how confident they are that the observed pattern represents an actual, real pattern of the phenomenon rather than merely an effect or artifact of the way the data were collected or has been presented. Teams meet to provide peer feedback on the Data Components, and on their draft Final Projects.

Session Goals

Theme	Goals
Climate Science Ideas	Engage in an activity and use a model to explore the causes and effects of sea level rise. Understand that: <ul style="list-style-type: none">• When heat energy is added to water, the water molecules move more and get farther apart from one another. This causes the water to expand, which causes sea level to rise.• Changes in sea ice, glaciers, and sea level are evidence that Earth's climate is getting warmer.
Using Data	<ul style="list-style-type: none">• Build on skills covered in previous sessions.

	<ul style="list-style-type: none"> • Explore ways to determine how confident one can be in a data pattern.
Learning & Teaching	Apply ideas from the learning sciences and effective practices and strategies introduced in the course to design effective activities to achieve deeper conceptual understanding.
Framework/NGSS	Examine how the Crosscutting Concept of cause and effect can support evidence-based connections about climate change.

Materials Needed

For the class:

- PowerPoint presentation
- Digital/data projector
- Whiteboard or flip chart paper and pens
- masking tape

For each participant:

- Evidence of Climate Change Chart
- Access to copy of *Final Project Guidelines* (distributed in Session 8)
- (Optional Extension) 1 copy of Sea Level Upper & Lower Bound worksheet

For each pair of participants:

- 1 set of Cause and Effect Cards
- 1 Sample of Student Cause and Effect Flowchart

For each small group:

- (Optional) 1 set of Organisms and Climate Change Information Sheets

For the Sea Level Rise activity

For the class

- land/ocean tub model filled with water to where the land starts to rise
 - see-through plastic tub approximately 6 inches deep and 18”W X 29”H
 - piece of foam that is about the same depth as the plastic tub and takes up about $\frac{1}{2}$ - $\frac{2}{3}$ of the tub (see image below).
 - drinking straw with tick marks evenly spaced and numbered (about .5 cm apart—each tick mark represents one meter)
 - thumbtack to tack straw onto foam land
 - pitcher of water
- 2 clamp lamps with 72-watt lightbulbs or heat lamps (clamp lamps work well if attached to bookends or a chair back)
- small cooler full of ice cubes (not crushed ice)
- 1 1-liter clear plastic bottle filled with warm room temperature water
- 1 rubber stopper (sized to fit the plastic bottle), with a small hole (sized to fit pipette or dropper)
- 1 glass dropper (without bulb) or short glass pipette, or other small clear tube to tightly fit into the stopper hole
- Water
- Scissors
- 1 3-inch piece of string
- 1 thermometer (to fit through mouth of clear 1-liter bottle)
- Food coloring
- 1 pushpin
- several books (teacher provides to raise level of bottle to nearer the lamp)
- 4 bookends (to attach clamp lamps)
- simulations, found at <http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence/oss68-overview/oss68-resources/unit1>
 - Scroll down to Session 1.1: Heat Energy and Moving Molecules; then click on Simulation: *Rising Temperatures* and
 - (optional) *States of Matter*

Per Group of 3-4 students:

- 1 color copy of each of sheets L-1 and L-2
- colored tape or masking tape
- 1 copy of directions for “Possible Causes of Sea Level Rise” investigation
- two 6-8 oz clear plastic solo cups with about 2-3 inches of water
- 1 rock that fits in the bottom of one of the clear plastic solo cups and takes up most of the bottom of the cup (the rock should not be so large as to emerge from the top of the cup)
- Optional: tray

Preparation of Materials

For Sea level rise activity: what is sea level rise

- 1. Prepare drinking straw to model a tide gauge.** Use a permanent marker to draw evenly spaced (about .5 cm apart) tick marks on a drinking straw. Number the tick marks —each tick mark represents one meter.
- 2. Prepare the land/ocean tub model.** Place the foam in the plastic tub and carve it to represent a landmass. The landmass should have a variety of topographical features so that it has different elevations at different points. The empty part of the tub represents an ocean basin. The land mass should rise rather abruptly along the coastline so that it represents a continental shelf, with the lowest point on the coastline being roughly 3 inches from the bottom of the tub. Hot glue it into the tub so that it is permanently in place.



3. **Just before the activity,**
 - a. Use the thumbtack to affix the drinking straw with tick marks to the foam so that the straw is vertical. The bottom of the straw should be about two inches lower than the lowest point on the surface of the foam land.
 - b. Add enough water to the tub so that the lowest part of the coastline is about level with the water, not submerged. It should look like ocean water meeting the land.

4. **Optional activity - Determine Upper and Lower Bounds.** Determine if you will have students do the Optional activity. Slides for the activity are included at the end of the ppt and there is an optional worksheet for students to use.

For Sea level rise activity: sea ice and land ice investigation - for small groups

1. **Set up “Possible Causes of Sea Level Rise” Investigation Trays (1 per table group).** Collect the materials needed for the “Possible Causes of Sea Level Rise” Investigation. Include a copy of the directions.
2. **Make copies.**
 - 1 copy of directions for “Possible Causes of Sea Level Rise” investigation
 - 1 color copy of each of sheets L-1 and L-2
3. **Plug in heat lamps.** If using clamp lamps, clip them to a bookend or the back of a chair.

For Sea Level rise activity: water bottle and thermal expansion investigation (OSS 1.1)

1. **Prepare water bottle setup.** (See Figure 1–1 on page 8 of Unit 1 OSS.) Cut a 3-inch piece of string and tie it to the thermometer. Stick the pushpin into the bottom of the rubber stopper and use it to suspend the thermometer inside the bottle. Just before the session, fill the bottle with water (see below). Add 5-10 drops of food coloring to the water in the bottle (until water is colored but not too dark to see the thermometer). Place a few books underneath to raise the bottle about 4 inches.
2. **Set up lamps.** (See Figure 1–1 on page 8 of Unit 1 OSS.) Clip each lamp to a pair of bookends and test the lightbulbs. Place the lamps so they face the midpoint of the bottle (one on either side) with the lightbulbs just 1–2 inches away from the bottle. Leave the lamps off for now. (Note that the figure shows only one lamp.)
3. **Preview simulation.** Practice projecting and manipulating *Rising Temperatures*.

Immediately before the session:

Fill water bottle. Completely fill the 1-liter bottle with slightly warm water (30°C or 80°F) so the bottle overflows. Push the stopper tightly into the bottle. Make sure no air space remains between the water and the bottom of the stopper. You should see water coming out of the hole in the stopper. It's important not to have any air in the bottle. Insert the glass dropper tube into the hole in the top of the stopper.

Other copies needed.

1 copy per participant:

- Evidence of Climate Change Chart

1 copy per pair of participants:

- Cause and Effect Cards
- Sample of Student Cause and Effect Flowchart
- (Optional extension) Sea Level Upper & Lower Bound worksheet

1 set per small group:

- (Optional) 1 set of 7 Organisms and Climate Change Information Sheets (from OSS 3.9)

Session at a Glance

Task	Description	Time (minutes)
A. Quick Write & Session goals	Participants respond in writing to a prompt about the causes and effects of climate change. Applying their understanding of the Cause and Effect crosscutting concept and their prior knowledge about climate change. Session goals are shared.	10
B. Discussion: <i>Peer Feedback on Data Components</i>	Participants share Part 4 of the <i>Data Components of Final Project</i> (completed for homework) with small groups to receive feedback.	25
C. Activity: <i>Sea level rise</i>	Participants explore images and data visualizations of sea level rise and generate questions, predictions and discuss their rationales related to its underlying causes. They then conduct investigations to test their ideas and draw conclusions based on the results. They end by generating additional questions about sea level rise.	30
D. Activity & Discussion: <i>Confidence in a Pattern</i>	Participants engage in an activity and discussion about the probabilistic nature of science through learning about looking at the variation in data around a line of best fit. They discuss what influence variation has on their confidence in data patterns.	20
E. Activity and discussion: <i>Causes and effects of Climate Change (OSS 3.6)</i>	Participants work collaboratively to make evidence-based connections between the causes and the effects of climate change. They then examine student work examples of this same activity and discuss student understanding of the science content.	30
F. Final Project: <i>Feedback from</i>	Participants share the draft Final Projects (completed for homework from the last session), with their small groups with similar Topic Area	50

<i>peers and instructor</i>	Questions as the instructor circulates. They revise their drafts as they apply and consider the design of the data lesson they are developing and specifically address the design of their lesson in regards to the learning cycle instructional model.	
G. Homework	<ol style="list-style-type: none"> 1. Continue work on Final Project. Due: _____ 2. Do a web search and reflect on global and local solutions to climate change. 	5
	TOTAL: 2 hours 50 min	170

Session Details

A. Quick Write

1. **Participants do a Quick Write.** Participants write for 5-10 minutes to the following prompts:
 - What are the causes and effects of climate change? What evidence is there for a cause and effect relationship?
 - What other topics in science might be framed through the crosscutting concept of cause and effect relationships?

2. **Turn and Talk.** Ask participants to turn to a partner and discuss their ideas about the prompts.

Share session goals

1. **Display session goals slide.** Display the goals and briefly introduce each with a description of how they are connected and flow from one to another.
 - **Climate science ideas:** Engage in an activity and use a model to explore the causes and effects of sea level rise.
 - **Using data:** Explore ways to determine how confident one can be in a data pattern.

- **Learning and teaching:** Apply ideas from the learning sciences and effective practices and strategies introduced in the course to design effective activities to achieve deeper conceptual understanding.
- **Framework/NGSS:** Examine how the Crosscutting Concept of cause and effect can support evidence-based connections about climate change.

B. Discussion: *Peer Feedback on Data Components*

1. **Peers review Part 4 of *Data Components of Final Project*.** Have participants partner with another group and exchange their Part 4 of the *Data Components of Final Project* worksheet (aka the Orientation, Interpretation, and Synthesis questions) and the print out of the data visualization they plan to use in the data lesson. As participants review each other's work, encourage them to:
 - use their experiences throughout the course working with data, as well as their own experiences in developing such questions for their own final projects.
 - provide constructive feedback regarding how the questions can be further refined to be more specific and helpful for scaffolding their future students.
2. **Provide troubleshooting help.** As the groups finish working on refining the prompting questions in Part 4 for their Final Projects, provide any troubleshooting help needed for plotting the data for their final projects or for other aspects of the Final Project components. As well touch base with the participants to see if they have any additional questions with regards to completing the Final Project.

C. Activity: *Sea Level Rise*

Tell participants that they will now do some activities that explore the phenomenon of global sea level rise.

What is sea level rise?

1. **Show slide images of areas that have been impacted by sea level rise.**

- a. Show a slide with image L-4. Explain that this is a picture of a house on Kiribati (pronounced Keer-uh-bas), a low-lying island nation in the South Pacific, formed from 33 coral atolls. The people of Kiribati frequently struggle with water inundation causing beach erosion and fresh water contamination due to sea level rise.
- b. Show a slide with image L-5. Explain that these are images from Hurricane Katrina (top left) and the destruction caused by a Nor'easter in 2007 (bottom right). In the face of higher sea level and more intense storms, coastal communities are at greater risk of rapid beach erosion and water inundation from destructive storms like these.

Tell participants that this sort of inundation is happening in different parts of the world and in recent years is becoming more of a problem.

2. **Turn and Talk: Sea Level.** Have participants turn and talk to the following prompts:
 - a. What does sea level mean?
 - b. How is sea level measured?

Tell participants that you will do a demonstration to help answer these questions.

3. **Introduce the land/ocean tub model.** Show participants the model. Explain that it represents the ocean and coastline. Point out the drinking straw with tick marks; this represents high tide for that portion of the day in meters. (Record this number on a sheet of paper or on the board).
4. **Represent low and high tides.** Remove a few cups of water (enough so the water level drops a couple of tick marks). Tell participants this new water level represents low tide about six hours later. (Record new water level tick mark number). Add water back. This is the next high tide about 6 hours later.
5. **Calculate average sea level.** Repeat step 3 (above) two or three times. Have participants calculate the average level overall. Explain that this is the average sea level at that particular location.

6. **Share about global average sea level.** Explain that each area in the world has an average sea level. The local mean (average) sea level is defined as the height of the sea with respect to a land benchmark, averaged over a period of time (such as a month or a year); long enough that fluctuations caused by waves and tides are smoothed out. Tell them that since the late 1900s scientists have also collected sea level data using satellites.

Share evidence of sea level rise and generate questions

1. **Introduce sea level rise data visualizations.** Break participants into groups of 3-4. Pass out the sea level rise graph (L-1) and global graphic of where sea level rise is occurring (L-2) to each group. Ask participants to look at the color key at the bottom of L-2 and discuss what they think the figure is showing. Point out that a) the black areas are continents and the colored areas are ocean water, and b) 0 is the average global sea level for that time period. Ask participants if they have any orientation level clarifying questions before they start to interpret the data. *[Note, if the question arises about how average global sea level is, you can explain as follows: average sea level is commonly arrived at as the mean of multiple measures from multiple ocean basins and represents the mean sea level from many different tidal datums.]*
2. **Explore sea level rise data visualizations.** Project a slide with the following interpretation questions:
 - a. What do these data visualizations tell you?
 - b. What questions do these visualizations raise?Give groups a couple of minutes to discuss the data visualizations with each other and to respond to the questions.
3. **Participants share ideas.** After a few minutes, stop group discussions and ask for volunteers to share what information they were able to glean from the visualizations in terms of the interpretation questions. *[Sea level has been rising quite steadily since 1870; the gray areas around the whitish-yellow average line show uncertainty, which accounts for inaccuracies from older equipment; sea level is not changing uniformly across the globe--it has risen in some places and fallen in others].* Record their observations and questions on the board. *[Note: If the*

question doesn't arise, you might consider asking "Do you have any ideas why sea level is rising in some places and decreasing in others?" Don't answer the question yet; see below (near the end of this Section C) for another opportunity to discuss this question after participants gain more evidence.]

4. **Participants synthesize data.** Project a slide with the following synthesis question and instruct participants to discuss the question with their table group. Don't have a whole group share-out yet.

- *What do you think might be causing sea level rise, directly and indirectly?*

Design investigations to explore possible causes of sea level rise

1. **Introduce some possible causes of sea level rise.** Show a slide listing some possible causes (with images) of sea level rise: melting sea ice (floating ice, e.g. icebergs), melting land ice (e.g. glaciers and ice caps), and/or water warming due to rising air temperatures. Tell participants that people often wonder if these phenomena might be causes of sea level rise.
2. **Make a prediction with a rationale about causes of sea level rise.** Ask participants to write down a prediction about which of these phenomena may contribute to sea level rise—and what their rationale is for their prediction. Once they have made their individual predictions, have them share their ideas with a partner or table group to get feedback and to discuss alternative predictions and rationales.

Instructor note: *If your participants are experienced with claim-evidence-reasoning and making hypotheses, you may decide to have them use the following sentence stem to make a hypothesis: If _____ were the direct/indirect cause of sea level rise, then _____, because _____.*

3. **Lead whole group share-out.** Ask for volunteers to share out their predictions and rationales. For each response, ask if there are alternative ideas, if there is enough evidence to support that prediction and rationale, how might they get additional evidence, and if the rationale makes

sense with what they know so far. Accept all responses and record their predictions and rationale on the board.

4. **Considering investigations to test predictions.** Show participants the materials and ask how they might use these materials to test each of these predictions regarding the causes of sea level rise—warming water, melting land ice, and melting sea ice. Give table groups five minutes to answer the following prompts:
 - a. Discuss possible investigations using only these materials.
 - b. Consider and discuss how the planned investigation will help to test each of the hypotheses about the causes of sea level rise.
 - c. Describe the expected results of each investigation.

Sharing ideas about warming water as a cause of sea level rise

1. **Groups share their ideas about ways to test for warming water as a cause of sea level rise.**
After a few minutes call on a volunteer to share how they will test out whether or not warming water is responsible for sea level rise. As they describe their investigation, ask them to clarify how the investigation design will help them to isolate this particular cause and what they predict regarding the results. Challenge them to describe their rationale and/or science concepts that provide support for their prediction and rationale. Ask others for different ideas about how to approach the question.
2. **Describe bottle investigation.** If no one suggests the bottle and tube investigation you have planned, describe the investigation. [*Hold up the bottle with stopper and pipette attached. Show that the water level is currently flush with the top of the stopper. Explain that you will shine the heat lamp on the test tube for several minutes.*]
3. **Small group discussion about how investigation answers question.** Have table groups discuss how this investigation will help to answer the question about the role of warming water in sea level rise. Have them work together and write down their prediction (with rationale) about what they would expect to happen in this investigation if warming water contributed to sea level rise,

cite any previous evidence and explain why. **Instructor note:** *don't lead a whole group shareout yet because participants will be gathering more evidence to make an explanation in the next part of the activity. [Some participants may explain the phenomenon accurately as follows: using the sentence stem If, then, because: If warming causes water to rise, then the water in the test tube will move up the pipette because the space between water molecules increases as water warms, leading to the water expanding in volume. This models what happens to ocean water as water temperature increases due to increases in air temperature.]*

4. **Start investigation - turn on heat lamp.** Start this investigation now by turning on the heat lamp, noting the height of the water, and the starting temperature. **[Instructor note:** *It may take 10 minutes for the temperature to go up $\sim 1^{\circ}\text{C}$ and the water in the tube to have risen about 3–4 centimeters.]*

Sharing ideas about melting land ice as the cause of sea level rise

1. **Groups share their ideas about ways to test for melting land ice as the cause of sea level rise.** Now focus on melting land ice as the possible cause of sea level rise. Call on a volunteer to share how they will test out whether or not land ice is responsible for sea level rise. As they describe their investigation, ask them to clarify how the investigation design will help them to isolate this particular cause and what they predict regarding the results. Challenge them to describe their rationale and/or science concepts that provide support for their prediction and rationale. Ask others for different ideas about how to approach the question.
2. **Describe investigation.** If no one suggests the investigation you have planned, describe the set up as follows: hold up the cup of water with a rock on the bottom. Explain that the cup with the rock will be used as a model to investigate what happens to sea level when ice on land, such as glaciers and ice caps, melts and flows into the ocean. The water level is below the top of the rock because the rock is representing the land. An ice cube will be placed on top of the rock to represent land ice and then the water level will be recorded with a marker (or a piece of tape) on the side of the cup.

3. **Small group discussion about how investigation answers question.** Have table groups discuss how this investigation will help to answer the question about the role of warming water in sea level rise. Have them work together and write down their prediction about what they would expect to happen in the investigation if melting land ice contributed to sea level rise, cite any previous evidence and explain why. [*If melting land ice causes sea level rise, then the water level will rise as the ice melts because more volume of water is being added to the model ocean.*]

Sharing ideas about melting sea ice as the cause of sea level rise

1. **Groups share their ideas about ways to test for melting sea ice as the cause of sea level rise.** Now focus on melting sea ice as the possible cause of sea level rise. Call on a volunteer to share how they will test out whether or not sea ice is responsible for sea level rise. As they describe their investigation, ask them to clarify how the investigation design will help them to isolate this particular cause and what they predict regarding the results. Challenge them to describe their rationale and/or science concepts that provide support for their prediction and rationale. Ask others for different ideas about how to approach the question.
2. **Describe investigation.** If no one suggests the investigation you have planned, describe the set up as follows: hold up the cup of water with no rock on the bottom and say that an ice cube will be added to the cup to represent sea ice (ice floating at sea). Explain that they will place an ice cube in the water and then record the water level with a marker on the side of the cup.
3. **Small group discussion about how investigation answers question.** Challenge table groups to discuss and write down their predictions about what they would expect to happen in the investigation if melting sea ice contributed to sea level rise and why they think that. [*If melting sea ice causes sea level rise, then the water level will rise in the cup as the ice melts because more water by volume is being added to the liquid water (the ocean). An alternative hypothesis is that - If melting sea ice doesn't contribute to sea level rise, then the water level will not rise in the cup as the ice melts because the volume of floating ice is displacing the same amount of water as the melted ice is already displacing.*]

Conduct investigations to explore causes of sea level rise.

- 1. Distribute Possible Causes of Sea Level Rise investigation trays.** Provide one tray of investigation materials and a direction card per table of participants. Ask participants to follow the directions for the investigations and talk in their table groups about what they observe. Each group will bring both of their cups up to the front of the room to share the same heat lamps with the entire class.
- 2. Share observations.** After table groups have completed their investigations (the cup experiments take about 5 minutes to run), ask for volunteers to share their observations. [*The water level in the test tube in the glass tube rose at the top; the water level in the land ice cup rose; the water level in the sea ice cup stayed the same.*]
- 3. Ask challenge questions - Turn and Talk.** Ask participants to turn and talk about the following prompts:
 - a. Why did the investigation directions include to measure the water level in the sea ice cup after the ice was added, rather than before. Would it make any difference? Why?
 - b. Why did the water level rise in the warming water investigation?
- 4. Volunteers share explanations.** After a few moments of discussion, ask for volunteers to share their explanations. [*a. The water level was measured after the ice was added to model sea ice floating on the ocean. The level was measured before the ice melted and again after the ice melted to determine if melting sea ice played a role in sea level rise. Floating ice does not increase the volume of the liquid (ocean or cup of water) when it melts because the amount of water it displaces as an ice cube is equal to the volume of the water after it melts. b. the heat lamp transferred energy to the water molecules, which caused them to move faster, as reflected in the increase in temperature of the water measured by the thermometer. As the kinetic energy of the water molecules increased, the molecules got further apart from one another which caused the water to expand and go up the tube.*]

Optional: Using a Simulation of Moving Molecules

Note to instructor: Depending on the experience of your participants, you may consider showing them the simulation to help deepen their understanding of the concept of thermal expansion on a molecular level.

- 1. Project *Rising Temperatures* simulation.** Project the simulation and explain that it shows a model of what happens to water molecules when water is heated. Point out the thermometer inside the bottle, temperature display, tube with hole in top, and the light bulb (which is off). Call on a volunteer to briefly describe the movement of water molecules (inside the magnifying glass) before heat is added.
- 2. Start simulation.** Click “on” beneath “HEAT.” Point out the time elapsed and that time is sped up for the simulation. Tell participants that the thermometer in this simulation only shows whole degrees; there are no increments between the whole numbers as they would record if they were taking the temperature with an actual thermometer.
- 3. Turn and Talk about simulation.** Tell participants to turn and talk with a partner about what they notice in the simulation by discussing the following questions:
 - How is the simulation similar and/or different from your mental model of what was happening at the molecular level?
 - What is happening to the water molecules as the water is heated? How would you describe the movement?
 - Do the molecules themselves get bigger?
 - How much does the temperature increase?
- 4. Whole group share out.** Invite participants to share their observations about the simulation. As ideas come up, rephrase their observations using scientific language.
 - *The water molecules wiggle faster and faster as heat energy increases. The heat lamp was transferring energy to the water molecules which caused them to move faster and get farther apart from each other.*

- *Molecules do not get bigger, but the space between them gets bigger as they move farther apart from one another.*
- *The temperature of the water in the bottle increases from 26°C to 28°C. The thermometer was measuring the kinetic energy of the water molecules; the increase in temperature showed that the kinetic energy of the water molecules increased.*
- *The water goes up the tube as the temperature rises, and the molecules move further apart from each other.*

5. Discuss accuracies and limitations of a model. Stop the simulation. Remind participants that the simulation is a model. Point out that the model is helpful for showing the movement of water molecules. Ask participants, how is this model an accurate representation of molecules, and what are its limitations? [*Limitations include: molecules are much smaller than they appear in the simulation and they don't look like colored dots; the model speeds up time. Accuracies include: movement of molecules and the amount of space between molecules change as heat energy changes.*]

Making claims and constructing explanations about causes of sea level rise

1. **Participants make claims.** Reshare the data visualization of where sea level rise has been occurring globally (project image L-2). Ask, “Based on the available evidence including this data visualization, what claims can you make about the causes of sea level rise?” [*Water takes up more space/rises when it gets warmer; ice melting on land goes into the ocean; melting sea ice does not appear to cause sea level rise; sea level rise happens unevenly, but it seems to impact warmer water more*]. As participants share their ideas, follow up by asking what others think, what others might add/agree/disagree with, how sure they are about their claims and how they could be more sure.

[Instructor note: You might use this opportunity to return to the question participants asked previously regarding why sea level is rising unevenly around the globe. Ask participants if they have any additional ideas that might explain this phenomenon. Share the following processes as possible causes leading to different sea levels in different areas if they do not come up: Depending on the region, some coastal areas are rebounding or subsiding as a result of the

change in massive glaciers that once covered the land; some areas are subsiding as a result of massive amounts of fossil fuels taken out of the underground carbon reservoir or the removal of water from the water table; prevailing winds may pile up or move ocean water away from shore; as glaciers and ice sheets shrink, their gravitational attraction of the water near them changes (more ice gravitationally holds onto more water around them leading to a higher sea level, e.g. the ice sheet's gravity is currently keeping sea level artificially low in the Northern Hemisphere and high around the poles); ocean currents may pile up water or pull water away from the coast, e.g. a cold ocean current phase on the US west coast has counteracted the effects of climate change and prevented sea levels from rising over the last 20 years.

Optional: have participants access one or more of the following websites for explanations

<http://ocean.si.edu/sea-level-rise>,

http://e360.yale.edu/feature/the_secret_of_sea_level_rise_it_will_vary_greatly_by_region/2255/,

<http://ww2.kqed.org/science/2015/08/26/nasa-rising-seas-about-to-catch-up-with-the-west-coast/>

2. **Participants generate questions.** Ask, “Based on the results of your investigations and this data visualization, what questions do you still have about the causes of sea level rise?” Accept all responses and record questions on the board.

3. **Share additional information.** Share that many scientists estimate that warming water taking up more space (thermal expansion) is directly responsible for around 50% of sea level rise, while melting land ice is directly responsible for much of the rest. Melting sea ice also indirectly affects sea level rise because as the ice melts, it leaves a darker surface behind (it was white ice and is now darker-colored ocean water). This darker surface in turn causes the Earth’s surface to warm more as less solar energy is reflected away from Earth’s surface. A warmer planet leads to further melting of land ice and further thermal expansion.

4. **Display the climate science ideas slide and encourage questions.** Show the slide with the science ideas listed below and have participants read it. Have them discuss with their table group how some of the following science ideas helps them to construct explanations about the causes of

sea level rise. Also have them discuss any questions they have, or anything in the investigation that surprised them. Accept all responses. *[Note: If participants are still wondering about why the water in the sea ice cup didn't rise, explain more about water displacement—that the ice in the cup was displacing an equal volume of water, so no additional water volume was added when the ice melted.]*

- When heat energy is added to water, the water molecules move more and get farther apart from one another. This causes the water to expand.
 - A warming atmosphere causes ocean water to warm and expand; thermal expansion directly causes about 50% of the sea level rise occurring now.
 - Melting land ice from glaciers and ice caps directly causes about 50% of the sea level rise occurring now.
 - Melting sea ice does not directly contribute to sea level rise because floating ice is already displacing the same volume of water it will displace when it melts.
 - Changes in sea ice, glaciers, and sea level are evidence that Earth's climate is getting warmer.
5. **Add climate science ideas to the Climate Sciences Ideas chart.** Elicit ideas from the class about how to organize the ideas on the chart regarding where to record them (i.e. which row and column) and whether the ideas are related to climate science concepts presented earlier in the course.

D. Activity and discussion: *Confidence in a Pattern*

1. **Project Confidence in a Pattern slide.** Tell participants that we will now further explore an important, though often overlooked, part of classroom science—how confident we are in a pattern based on the variation of the data. Explain that there is naturally occurring variation in all data in science. An important aspect of making scientific conclusions from an interpretation of data is being able to look at that variation and deciding how confident you are in the pattern. This is why

scientists always report statistical analyses when presenting their findings, as that is a mathematical way of discussing whether the pattern is an actual pattern or whether there is too much variation in the data to determine if it is a pattern. In other words, how confident are the scientists in stating that it is a pattern.

2. **Introduce activity.** We don't actually need to run statistics to get a sense of confidence in the data pattern, we just need to look at the data. We will use sea level data to demonstrate the concept of confidence in a pattern and explore ways of thinking about confidence that can be used with middle school students.

***Note to instructor:** The specifics of how the data were collected and what the data demonstrate are not the focus of the activity. For your knowledge, the data were downloaded from the NOAA Tides & Currents website's Tides/Water Levels / Mean Sea Level Trend data for Atlantic City, NJ (http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8534720). The data are calculations of the mean sea level "without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents." For this activity the original dataset (Figure B) is the mean monthly data when available from January and July each year of the time series. Figures A, C, and D contain adjusted data to demonstrate the lesson of confidence in a pattern with greater or lesser variation around the pattern/trend line. The plotted red line on each figure is the line of best fit of the data (linear).*

Your participants don't need to understand the level of detail of the data described above, however, they will need enough context to think through the activity at a theoretical level. The activity below provides the needed context, however depending on your participants, you may decide to add or remove information.

3. **Introduce Sea Level Average Data.** To explore the concept of confidence in a pattern, have participants look at adjusted January and July mean monthly sea level data from 1911 to 2015. The original data were provided by NOAA and are from around Atlantic City, NJ. First orient participants to what this graph is showing (Adjusted Sea Level Data Orientation - Average slide).

- a. Y-axis is Adjusted Sea Level Measurement (m)
 - b. X-axis is time from 1911-2015, with up to two points per year (January, July)
4. **Turn and Talk – Data Interpretation.** Have participants turn and talk about what relationship they are seeing between time and sea level in the figure (Adjusted Sea Level Data Interpretation slide). Be accepting of all answers and don't offer anything yourself to the conversation at this time, but instead encourage participants to share their thoughts and discuss with one another.
Prompt:
- a. Is there a relationship in these data? If so, what kind of relationship is it (positive or negative)?
5. **Class Check-in on Relationship in Data.** After 1-2 minutes, regain the attention of the class and have the students volunteer their opinions of what kind of relationship can be observed in the data. Help participants come to an agreement that there is a positive relationship in the data (data interpretation, red line is the line of best fit) – over time the mean sea level increased (data synthesis; Adjusted Sea Level Data Synthesis slide).

Confidence in science patterns - how confident are you?

1. **Focusing on the confidence in science aspect.** Tell participants that scientists not only determine what the pattern or relationship in their data is but also how confident they are that the observed pattern represents an actual, real pattern of the phenomenon rather than merely an effect or artifact of the way the data were collected or has been presented. Using the Adjusted Sea Level Data - How Confident Are You? slide, have participants raise their hands to determine how many are: very confident, pretty confident, or not at all confident in the relationship.
2. **Show *Exploring Confidence in Adjusted Sea Level Data* slide.** Point out that all of the graphs have a positive relationship (highlighted in the red lines of best fit) but the variation in the data is different. Ask participants to talk with their partner about the four figures and answer the prompting questions:

- a. How confident are you in the relationship (very confident, pretty confident, not very confident) in Figures A, B, C, and D?
 - b. What are your reasons for your level of confidence in the relationship for Figures A, B, C, and D?

3. **Whole group discussion - participants' confidence in the data.** After a few minutes bring the class back together and ask for general comments from the participants about their confidence in the relationships within each figure. Be accepting of all comments, and remind participants that there is no right or wrong answer, but rather this is exploring the concept of confidence.
 - a. How confident are you in the relationship (very confident, pretty confident, not very confident)? [*For Figures A and D scientists would most likely state they are "not very confident" in the pattern, for Figure B scientist would most likely state they are "pretty confident" in the pattern, and for Figure C scientists would most likely stated they are "very confident".*]
 - b. What are your reasons for your level of confidence in the relationship? [*For Figures A and D, scientists would most likely state they are "not very confident" in the pattern as there is a large range, or variation, in the data around the trendline, in that the top of the range of the data from the start (1910s) is similar to the bottom of the range at the end (2010s) indicating there is not much difference across time. For Figure B, scientist would most likely be "pretty confident" in the pattern as there is not too large of a range in the data around the trendline and there is definitely a difference in the values at the top of the range at the start (1910s) and the bottom of the range at the end (2010s). For Figure C, scientist would most likely be "very confident" in the pattern as there is only a little range in the data around the trendline and there is a large difference in the values at the top of the range at the start (1910s) and the bottom of the range at the end (2010s) indicating there is a difference across time.*]

4. **Introducing confidence statistics.** As the conversation slows down, explain (as some of them likely mentioned), that it is difficult to think about our confidence in this pattern as we are only looking at the data and trendline. What one person may feel is "Very confident" another may feel

is “Pretty confident.” Tell the participants that scientists use statistics to provide them with evidence about how confident they can be in the observed relationship in data, as they cannot report on their opinions from observing the data (though that is an important first step that scientists use in looking at their data in the analysis phase).

5. **Brainstorm how to take confidence concept to middle school students.** Tell participants that they don’t need to teach middle school students advanced statistics, and the students don’t need to know statistics to understand the concept of confidence. Ask the participants to turn and talk to someone near them about: how can we bring this concept of confidence to our middle school students?

6. **Debriefing how to teach confidence to middle school students.** After a few minutes, have participants share their brainstorms and thoughts about teaching the concept of confidence in a pattern to middle school students. Capture ideas in a class brainstorm list. If the following things do not come up, add them to the conversation:
 - a. *It’s extremely important to teach middle school students about the probabilistic nature of science, meaning that in science, things are never proven and we never can predict an exact value or outcome. Instead in science we look at the data and determine how confident we are in a pattern, prediction, outcome, or relationship.*
 - b. *One way to help students with this concept is to ask the students to present both a range of data and the line of best fit to understand the pattern, and their confidence in the pattern, rather than a single value when answering questions about the data.*

7. **Display Confidence in a Pattern Summary slide.** Review the slide with participants.

Optional Extension Activity: *Calculating Confidence Intervals takes a specific statistical analysis. While it is not appropriate to teach middle school students how to calculate Confidence Intervals you can introduce them to the practice of visualizing the range of the data by drawing Upper and Lower Bounds.*

Drawing Upper & Lower Bounds to demonstrate variation

1. ***Introduce and demonstrate how to draw Upper & Lower Bounds.*** *One of the tools that scientists often use are Confidence Intervals¹, which enable scientists to indicate how well a line of best fit represents the measured data or, said differently, how much variation there is in the data around the line of best fit. However, calculating Confidence Intervals involves complex statistics, which is more advanced than is appropriate for middle school students. One step to helping students see the variation in the data is to teach them how to draw Upper & Lower Bounds around their data so that they can determine how confident they are in the pattern of the line of best fit.*
 - a. *In order to create Upper & Lower Bounds, which act as an uncalculated Confidence Interval, you need to look at the full range of the data.*
 - b. *Use the Adding Upper & Lower Bound to Adjusted Sea Level Data slides to demonstrate how to draw in Upper Bound (Figure B Upper Bound slide) by making a line that connects most of the farthest out value points above the line of best fit.*
 - c. *Then continue on to the Figure B Lower Bound slide that connects most of the farthest out value points below the line of best fit to draw the Lower Bound.*
 - d. *After you have talked through how to create Upper & Lower Bounds, have the participants work with their partners to draw Upper & Lower Bounds on Figures A or C using the “Sea Level Upper & Lower Bound” worksheet.*

2. ***Debriefing Upper & Lower Bounds.*** *As the participants complete the Upper & Lower Bounds for Figures A or C ask them to think through how adding Upper & Lower Bounds to a figure may change their student’s perspective on how confident they are in the relationship of the data. Be accepting of all answers and encourage the participants to talk to one another about their opinions. As the conversation slows down, if it hasn’t*

¹ There are multiple ways to mathematically calculate a confidence interval around your data. However, teaching participants, and their middle school students, the statistics of calculating confidence intervals is not what we recommend. Instead, by using this exercise of creating trend lines by looking at the data, you can give participants (and their students) the understanding and language to enable them to talk about data and patterns in relation to their confidence in the data pattern as scientists do.

come up, point out that by drawing Upper & Lower Bounds through the outermost data points it becomes easier to see the full range of data around the line of best fit. This can also help a student to compare if the difference between the range of data points at the beginning and the end of the time series are all that different from one another, which is another thing that scientists look at when thinking about their confidence in the pattern. Having students look at Upper & Lower Bounds can reinforce looking at the variation in the data, similar to how scientists calculate Confidence Intervals and statistics for data.

E. Activity and discussion: Causes and Effects of Climate Change (OSS 3.6)

- 1. Introduce the Evidence of Climate Change Chart.** Distribute the *Evidence of Climate Change Chart* to each participant. Ask participants to work with a partner or small group to add information to the chart based on evidence they have gathered. Remind participants that scientists, who base their explanations in evidence, are continuing to gather new evidence as they study changes to the planet when exploring evidence of climate change. *[For example: sea ice, sea level, glaciers, temperature, organism distribution and biodiversity, changes in extreme weather events, changes in the amount of C in different reservoirs such as amount of CO₂ in the atmosphere and ocean.]*
- 2. Introduce cause and effect cards and activity.** Tell participants that they will now work with a partner to build another flowchart using cause and effect cards to show connections, much like they did in a previous session regarding ocean acidification. Provide each pair with a set of cards and scissors to cut the cards apart. Explain that as they work together, they should discuss how to place the cards to create a flow chart, discuss the evidence for each cause/effect connection, add evidence along the lines joining the cards, and share their reasoning.
- 3. Examining student work.** After about five minutes, regain the attention of the participants. Explain that now that they have had the opportunity to experience the activity, they will examine some student flowchart examples, and think about how this work could help them assess a student's understanding. Distribute the student work examples, and project the prompts:

- What does the student understand? How do you know?
 - What does the student need further support to understand? What makes you think that?
 - What could the instructor do to support this student?
4. **Whole Group Discussion.** Facilitate a whole group discussion. Remember to use the discussion map to encourage participation and challenge everyone to share their reasoning and evidence.
 5. **Optional: Organisms and Climate Change Information Sheets.** Distribute one set of the Information sheets to each small group and give participants a few minutes to distribute them among their group and divide up the reading between them. Tell them to share what they read with their group and then add any appropriate information to the Evidence of Climate Change Chart to get a more complete understanding of the effects on organisms.

F. Final Project: *Feedback from peers and instructor.*

1. **Small peer groups review drafts of Final Projects.** Have participants join their Final Project partners and other partner groups that they have worked with previously during the Session. Remind them that at this point they should have a quite complete draft of the different components of the Final Project on which to refine and make revisions based on feedback. Have each group share with each other their draft write-up of their final project, including all aspects outlined in the *Final Project Guidelines* handout. Encourage them to ask questions and obtain troubleshooting advice from peers and instructor.
2. **Partners revise their Final Project.** Encourage participants to add any additional information or revise their lesson based on feedback from their classmates regarding important aspects of each of the learning sciences and effective practices and strategies introduced in the course. Remind them to give particular focus to how the final project addresses the Learning Cycle. After small groups receive feedback, provide partners with time to work together. Circulate around the room answering questions and providing feedback as necessary.

G. Homework

1. **Complete the final project.** Due: _____

2. **Web search and reflection on global and local solutions:**
 - a. **Explore Globally.** Look on the web for two proposed solutions to lessen the effects of **global** climate change. Remember that this exploration is focused on **global** effects and solutions.
 - b. **Reflect and Write Locally.** Explore the effects of climate change in your **local** area or region. Write out responses to the following prompts:
 - Think about your **local** ecosystems, natural environments and/or natural resources. What **local** changes do you think you will see in these as a result of global climate change?
 - What are some of your **local** communities (see example below), cultures, economies, industries (e.g., shellfish and/or seafood industry), and/or businesses (e.g. agriculture, marine transportation, etc.) that rely on marine resources, the ocean, or other natural resources that are susceptible to effects of climate change? How will **local** effects of climate change have an effect on these?
 - For example, in Alaska and British Columbia, many Native American and First Nation communities are being displaced by sea level rise and having to leave ancestral lands behind. In other parts of North America, communities that have relied on the ocean for subsistence and income are no longer able to do so.
 - What effects of climate change are being addressed by **local** governments, communities and/or individuals? (Note - Consulting sources of local media is a good way to investigate this question.)

