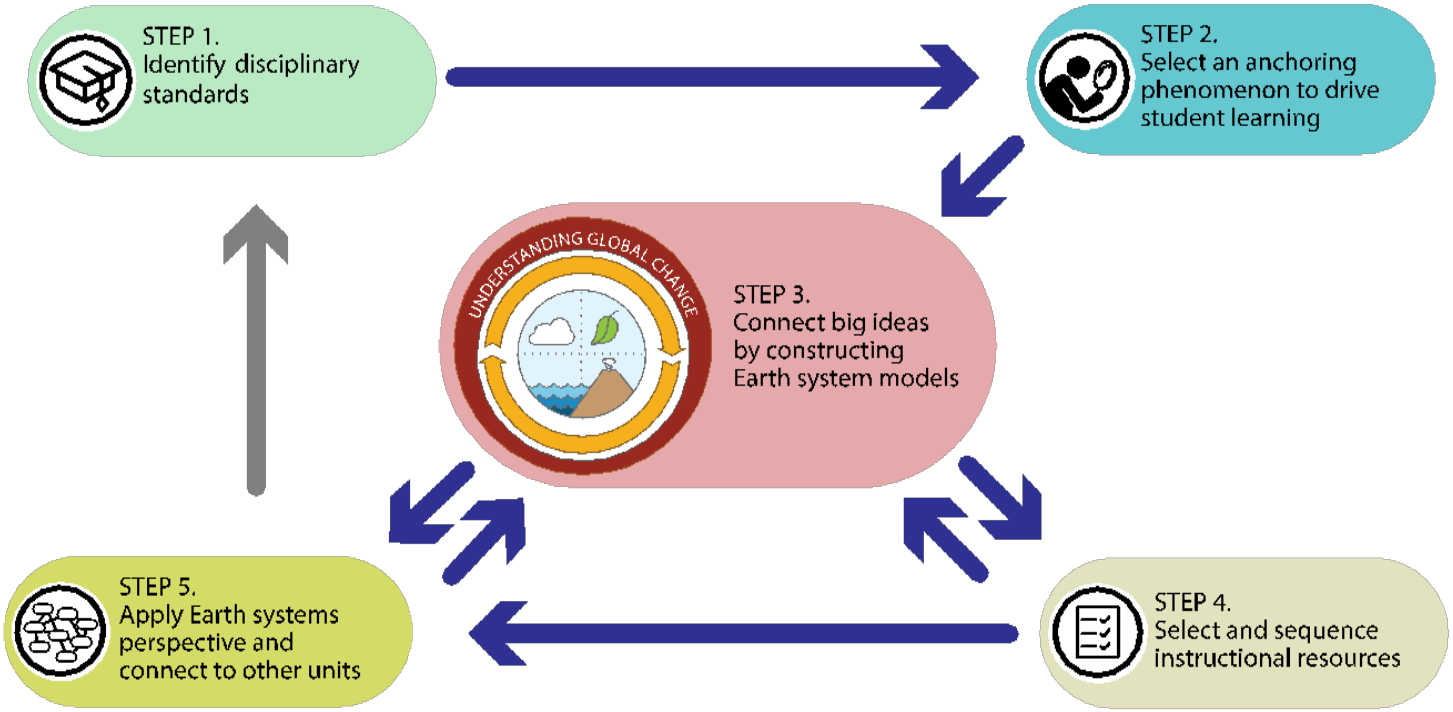
UNDERSTANDING GLOBAL CHANGE

SEA LEVEL RISE UNIT PLANNING GUIDE

This guide outlines the five key components of the **Sea Level Rise Unit** that incorporate the Understanding Global Change (UGC) Framework and Earth system modeling tools. This unit was codesigned with classroom teachers with support from BSCS Science Learning and CLEAN educators.* The unit can be modified to meet the needs and interests of your students, and ideally will support ongoing learning and thinking about the Earth as an interconnected, dynamic system. The instructional practices described below are also informed by resources from Ambitious Science Teaching and Next Generation Science Storylines.



*This resource was designed in collaboration with Heather Arnold (Novato High School) and informed by a pilot study supported by BSCS Science Learning with 23 teachers in the San Francisco Bay Area.

STEP 1. Identify disciplinary standards

The table below summarizes the grade level standards addressed in this unit, and how this unit could connect to content in other parts of your curriculum. If you are using the **Next Generation Science Standards**, please refer to the **UGC-NGSS Crosswalk** spreadsheet to explore the K-12 standards that are relevant to each topic/ icon in the **UGC Framework.**

Course/ subject area	Integrated Science, Earth Science
Grade level/ age	High School (Adaptable for Middle School)
Disciplinary/ curricular standards	HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.
Relevant UGC topics/icons and other concepts	water cycle, clouds, precipitation, freshwater quality and availability, freshwater use, snow and ice cover, solar radiation, air and water temperature, greenhouse gases, greenhouse effect, sea level rise, displacement of human populations, habitat restoration, burning of fossil fuels, agricultural activities, pollutants and waste
Prior knowledge (*Content or disciplinary standards, such as NGSS Performance Expectations, that were addressed in this or another courses prior to this unit of study.)*	Relevant to HS ESS2-2 : 5-ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. 5-ESS2-2. Describe and graph the amounts and percentages of water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth. MS-ESS2-4. Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity. Relevant to HS ESS3-1: MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. Additionally, students should be familiar with what causes tides, which is related to MS-ESS1-1. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.
Unit time requirements	17 lessons, approximately 50 minutes each, approximately 4-5 weeks
Curricular connections & extensions *(Topics/ icons relevant to the unit that could extend the learning experience.)*	UGC Icons: Renewable energy, ocean circulation (thermohaline/ salinity changes with ice melt), precipitation patterns, species populations and species interactions (food webs) affected by ice melt, ocean acidification (due to increased carbon dioxide levels in the atmosphere).

STEP 2.A. Phenomenon criteria checklist

An anchoring phenomenon is used to focus, motivate, and sustain students' interest in learning. Students will construct an explanation of the causes and consequences of sea level rise over the course of the unit. As students figure out what causes sea level rise, they should demonstrate their understanding of the Earth as an interconnected system.

Description of the anchoring phenomenon: Sea level rise is a global phenomenon documented by communities and scientists around the world.	
Relevant UGC Measurable Changes: Sea level rise, snow and ice cover, air and water temperature, greenhouse gases, displacement of human populations	
• Does an explanation of this phenomenon require connecting ideas from all three categories of the UGC framework (Causes of Global Change, How the Earth System Works, and Measurable Changes in the Earth System)?	**Yes/ No, Explain: Yes:** To explain sea level rise, students must understand how the burning of fossil fuels, agricultural activities, deforestation, and pollutants and waste affect the water cycle, the greenhouse effect, and the re-radiation of heat. Changes in these processes result in measurable changes in sea level rise, temperature, greenhouse gases, and snow and ice cover, and the displacement of human populations.
• Is this phenomenon an observable event that happens over time? (*Phenomena could occur over a short or long time period, and can be experienced by direct observations or second hand through images, video, and/or datasets.)*	**Yes/ No, Explain: Yes:** Global sea level rise has been documented over the last 150 years (see https://climate.nasa.gov/vital-signs/sea-level/), and is experienced through direct experience/ observation, images, and datasets.
• Does this phenomenon happen in a particular place? (*Phenomena can occur over small areas or large geographic regions, and should be events and changes that are context-rich.)*	**Yes/ No, Explain: Yes:** Coastal communities around the world are affected by sea level rise.
• Does this phenomenon have the potential to be explored through a variety of engaging resources (e.g., observations, pictures, videos, datasets) and investigations (classroom and outdoor experiences)?	**Yes/ No, Explain: Yes:** This unit includes pictures, videos, datasets, and classroom investigations.

• Does this phenomenon have the potential to motivate and sustain students' interest and purpose for learning?	**Yes/ No, Explain: Yes:** 40% of the world's population lives within 60 miles of a coastline, which makes sea level rise a locally relevant topic to many students. Ideally, local images and datasets should be used during instruction, and learning can be applied to evaluating solutions to protect local communities. Resources about sea level rise mitigation and adaptation in the San Francisco Bay Area are provided in the example unit.
• Does this phenomenon connect to prior student classroom or out-of-school-time experiences?	**Yes/ No, Explain: Yes:** Students have likely seen news reports about ice melt and sea level rise, and may have experiences periodic flooding in their own communities, or seen images of nearby regions that are being affected by sea level rise. Also see prior knowledge section in STEP 1 above.

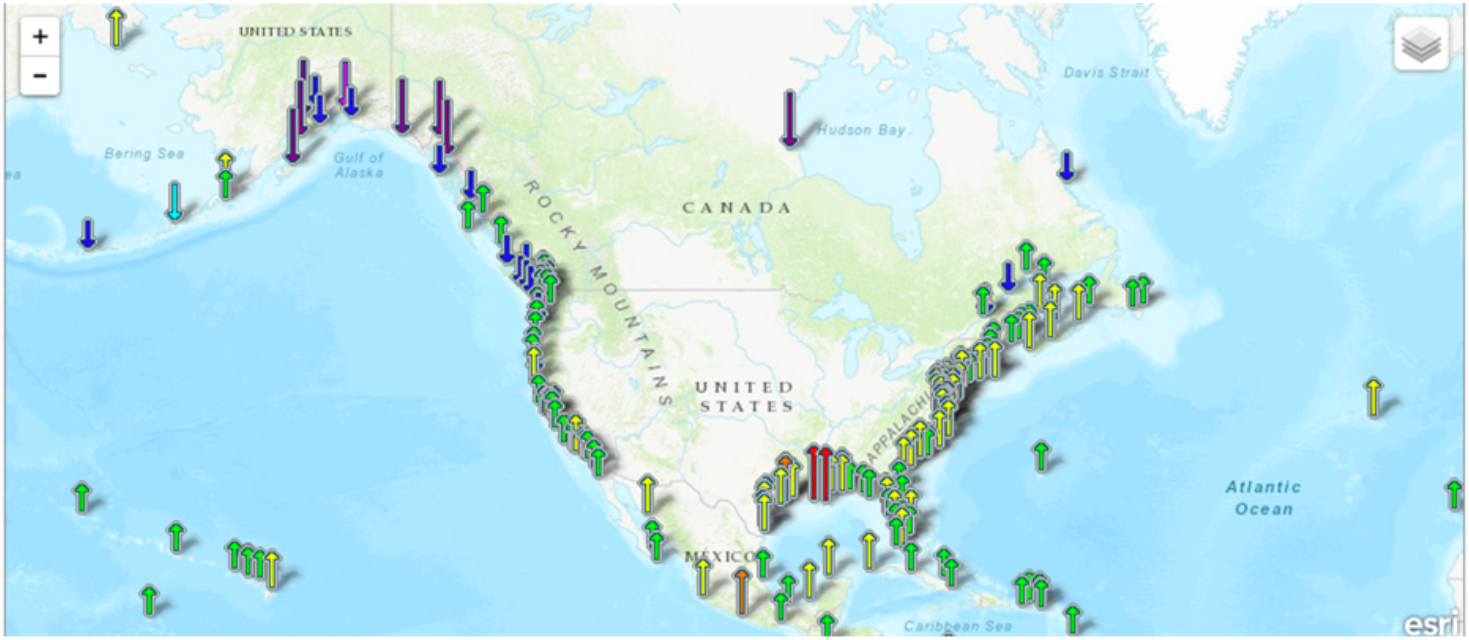
STEP 2.B Introduction to the phenomenon, unit driving question, and eliciting students' ideas

Below are resources that can be used to **introduce sea level rise as a phenomenon**. Even though this phenomenon is measurable around the world, students are also more likely to be interested in this topic if the introduction provides a connection to human experiences and/or local environments.

To help focus and engage students in their learning, formulate a **unit driving question** about the anchoring phenomenon. The driving question should not be answerable with a yes/no response, and should require students to connect ideas throughout the unit. Driving questions that are sufficiently complicated often include the words how or why. Student responses to the driving question can be revised and revisited as the unit progresses. All activities and learning experiences in the unit contribute in some way to students' ability to answer the driving question.

Following the introduction of the phenomenon, students should have the opportunity to record, discuss, and share their initial ideas about the anchoring phenomenon. A subset of relevant **UGC icons** and the **Earth scene** could be used to help students organize their initial ideas. Please also see **Ambitious Science Teaching** resources for ideas about eliciting students' ideas.

Table 2.B Introduction to the phenomenon, unit driving question, and eliciting students' ideas

Resource(s) to Introduce the anchoring phenomenon	Introduce images, maps, graphs from: ● Sea Level Trends, NOAA - https://tidesandcurrents.noaa.gov/sltrends/sltrends.html (zoom in on map to focus on regional changes) ● U.S. Sea Level Trend Map, NOAA - https://tidesandcurrents.noaa.gov/sltrends/slrmap.html ● Climate Change: Global Sea Level, NOAA Climate.gov - https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level Additional image sources: ● https://www.nytimes.com/2016/07/03/world/asia/climate-change-kiribati.html ● https://projects.sfchronicle.com/2016/sea-level-rise/part1/ ● http://www.miamitodaynews.com/2016/09/13/miami-getting-serious-sea-level-rise We recommend using a combination of images and maps highlighting local changes in the coast near your community, and then show the global map to provide a broader context for the phenomenon.  Sea Level Trends, NOAA

Driving question(s)	**How and why are sea levels changing? Later in the unit, this question can be extended to include, How will sea level rise impact humans? How can communities mitigate and adapt to sea level rise? These questions could also be modified to address local changes (e.g. How and why are sea levels changing in the San Francisco Bay Area? How will sea level rise impact communities in the San Francisco Bay Area? How can our community mitigate and adapt to sea level rise?)**
How students' ideas and prior knowledge/ experiences will be elicited and made visible/public	Introductory example script (see Deck 1 Slides 2-5): Over the next few weeks, we will be investigating a change that is occurring around the world and in our local (or nearby) community. Images taken from along our coast show ocean water sometimes coming into places where people live and work during high tides. Other communities in Florida, the Pacific islands, and Indonesia, are also experiencing periodic flooding. Data collected around the world by scientists at National Oceanic and Atmospheric Administration (NOAA) are trying to help us understand why people are experiencing these changes. Take a look at the maps and think about what you observe. What patterns do you notice in these data? What do the size and color of the arrows mean? Students will (see example slides 6-11): • Take two minutes to write down your initial ideas about how and why might sea levels be changing locally and around the world. • Chat with a partner for two minutes about what they observe. How are their ideas similar or different? • In groups of 2-4, construct initial models explaining how/why sea levels are changing (explained in STEP 3 below). Write down any questions they have about how and why might sea level be changing locally and around the world on sticky notes .

STEP 2.C. Explanation of the phenomenon, investigative questions, and relevant UGC topics

In the table below is a coherent explanation of the anchoring phenomenon and questions that will be addressed in the unit to explain sea level rise. These questions will be sequentially investigated and answered using various activities and resources in the instructional sequence in STEP 4. The table also contains the concepts from the UGC Framework that are relevant to each part of the explanation that will be used to develop Earth system models and explanatory statements about the phenomenon in STEP 3. You might want to modify the sequence of ideas if you are adapting this unit for your classroom and connecting this phenomenon to prior student learning.

Table 2.C Explanation of the phenomenon, investigative questions, and relevant UGC topics

Explanation of the anchoring phenomenon:	Investigative questions/anticipated student questions about this part of the explanation:	UGC topics/ icons relevant to this part of the explanation
Explanation Part 1: Sea levels are rising around the world. The water contributing to sea level rise is from glaciers and ice caps. Glaciers and ice sheets store water on land. When they melt, this water enters the ocean, causing the sea level to rise. Glaciers take a long time to form, and water can remain in glaciers for hundreds of years.	What is/are the source(s) of water that are contributing to changes in sea level? How do we measure sea level rise? How is water distributed in different places on Earth? (Related question: Is there more water on Earth? Or does water just move between different places?)	*Sea level rise, Water cycle, Snow & ice cover*
Explanation Part 2: The rate at which glaciers are melting has increased over the last 100 years. This increase in the melting rate of Earth's land ice is due to rising average temperatures.	What increases the rate of ice melting? Is the pattern of ice melting the same everywhere on Earth? Why is Earth's average temperature increasing?	*Snow & ice cover, Air temperature*
Explanation Part 3: Earth's rising average temperature is caused by an increase in greenhouse gases in the atmosphere due to human activities. Greenhouse gases re-radiate heat in Earth's atmosphere, impeding its loss to space.	What is causing an increase in Earth's average temperature? What are greenhouse gases and how do they work? How does a warmer atmosphere make ice melt?	*Greenhouse gases, Greenhouse effect, Re-radiation of heat, Air temperature, Agricultural activities, Burning of fossil fuels, Deforestation, Pollutants & waste*
Explanation Part 4: The oceans and atmosphere exchange heat. As the atmosphere warms due to the enhanced greenhouse effect, the oceans are absorbing a lot of that extra heat. As the temperature of the oceans increase, thermal expansion occurs. Thermal expansion, in addition to land ice melting, contributes to sea level rise.	How does a warmer atmosphere make the ocean warmer? What happens to water molecules as water is heated? What can we observe and what is invisible? What is thermal expansion? How much of sea level rise is due to thermal expansion of the oceans?	*Air temperature, Water temperature, Sea level rise*
Explanation Part 5: Coastal communities will be impacted and displaced as sea level rises. Reducing greenhouse gas emissions is needed to mitigate climate change. Restoring marsh habitats naturally buffers coastlines from rising tides.	How can we mitigate and adapt to sea level rise in our community? Why is tidal marsh habitat restoration useful for mitigating the effects of sea level rise (in the San Francisco Bay Area and other communities)?	*Displacement of human populations, Habitat restoration,*

STEP 3. Connect big ideas by constructing Earth system models

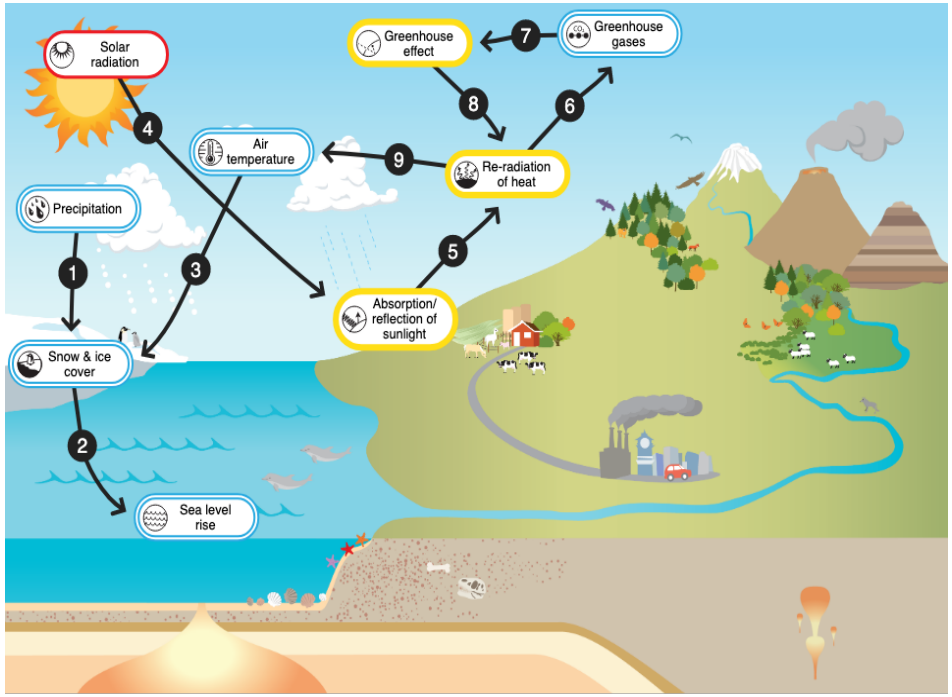
Visualizing Earth system cause and effect relationships between the UGC topics/icons can help determine the coherency of the unit, and how you might want to modify the unit to reflect prior student learning. Similarly, the construction of Earth system models can help students identify gaps in their own explanations of the anchoring phenomenon that they need to explore in order to answer the unit driving question.

STEP 3.A. Example unit models and explanations of Earth systems connections

The Earth System models below contain the connections among UGC icons/topics that you expect students to make as they progress through the Sea Level Rise Unit. Each connection has an associated explanatory statement about the cause and effect relationships between the UGC icons that can be determined based on evidence from the learning experiences in the unit.

Unit models

Example model from lessons 1-9:



Example end of unit model:

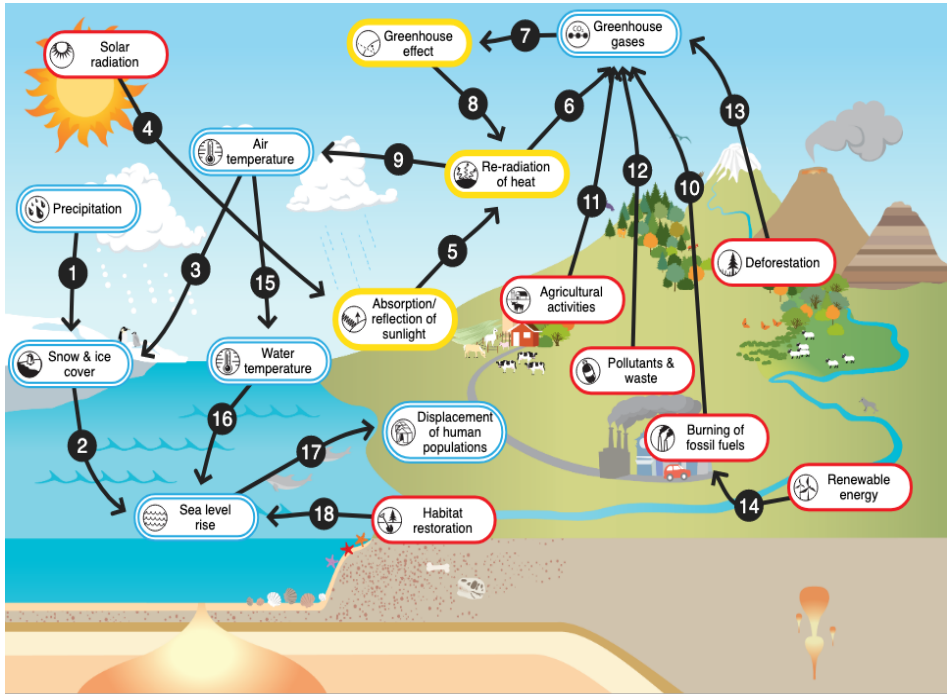


TABLE 3.A Earth System Connections

Topics/icon connection	Student target explanations of system connection
1. Precipitation (Water cycle)→ Snow & ice cover	Precipitation that falls as snow can contribute to snow and ice on land, some of which becomes ice in glaciers and ice caps.
2. Snow & ice cover → Sea level rise	Melting ice on land (i.e. glaciers) makes the sea level rise, while melting ice in the ocean does not contribute to sea level rise.
3. Air Temperature → Snow & ice cover	As the air temperature warms it causes the snow and ice to melt. Land and sea ice is melting at faster than historical rates.
4. (beginning of explanation of the Greenhouse effect and global warming) Solar radiation → Absorption/reflection of sunlight	Sunlight reaches the surface of the Earth and is either absorbed or reflected. Light that is absorbed heats the surface of the Earth, the atmosphere, and the ocean.
5. Absorption/reflection sunlight → Re-radiation of heat	The light that is absorbed is also reradiated as heat from the surface of the Earth (the Earth emits infrared light)
6. Re-radiation of heat → greenhouse gases	Greenhouse gases in the atmosphere, such as methane and carbon dioxide, let visible light pass through, but absorb and re-radiate heat.
7. Greenhouse gases → greenhouse effect	When greenhouse gases radiate heat this creates the greenhouse effect. The greenhouse effect slows the loss of heat from the Earth to space. causing an increase in air temperature.
8. Greenhouse effect → Re-radiation of heat	The greenhouse effect slows the loss of heat from the Earth to space by absorbing and re-radiating heat.
9. Re-radiation of heat → Air temperature	This increase in re-radiation of heat by greenhouse gases increases air temperatures.
10. Burning fossil fuels → greenhouse gases 11. Agricultural activities → greenhouse gases 12. Deforestation → greenhouse gases 13. Pollutants & waste → greenhouse gases	Human activities, including burning fossil fuels, agricultural activities, certain pollutants and waste, and deforestation all release the greenhouse gas.

TABLE 3.A Earth System Connections (Continued)

Topics/icon connection (continued)	Student target explanations of system connection
14. Renewable energy → Burning fossil fuels	Renewable energy sources (i.e. wind, solar) are essential to reduce the burning of fossil fuels and reducing greenhouse gas emissions.
15. Air temperature → Water (ocean) temperature	The greenhouse effect causes the atmospheric air temperature to rise, and much of this added heat is absorbed by the oceans, increasing ocean water temperatures.
16. Water temperature → Sea level rise	As the ocean temperature rises, this also causes the ocean to thermally expand, contributing to sea level rise.
17. Sea level rise → Displacement of human populations	Sea level rise is an immediate threat to coastal communities all over the world, potentially leading to displacement of many populations.
18. Habitat restoration → Sea level rise	Restoration of marshes can create natural protection and help communities be resilient when adapting to sea level rise.

STEP 3.B. Planning for student models construction

Modeling makes students' ideas visible and provides evidence that students can coherently construct and refine their explanations of the anchoring phenomenon as the unit progresses. After you construct exemplar Earth system models in STEP 3.A, determine how students will make sense of their learning experiences by constructing their own models. Model building could be done at various stages in the unit in small groups, individually, and as class discussions. Students should have opportunities to revise their models at least twice during a unit and to collaborate with peers to construct consensus models. If students are not able to construct the anticipated example models and Earth system connection explanations developed in section 3.A, then the unit may not be coherent from the students' perspective and should be revised or enhanced with new resources.

TABLE 3.B Planning for student models construction

Modeling activities: What will students be doing? Will students work individually, in pairs, groups, or during a facilitated class discussion?	**Materials, scaffolds, and practices to support the construction of Earth system models**
Lesson 1: Initial Model Students use the information provided in the introduction to the phenomenon to answer the driving question. Students use diagrams and words to represent their ideas. Groups share out initial models. Students will model their ideas individually, and then build a model in groups of 2-4.	Materials: Chart paper or UGC Earth Scene 11x17 or 18x24 color or black and white posters (1 per group), dry erase markers (if using laminated Earth scene posters) The components of the Earth scene can help prompt student thinking about parts of the Earth system and reduce the amount of drawing necessary to express those ideas. Instructions from Deck 1, Slides 6-11: Use your ideas to construct a model using words, diagrams, and arrows what you can **see** and what you think might be happening that you **can't see**. There are many ways to communicate your ideas. The purpose of this model is just to get your first ideas out on paper. We don't expect to have correct answers yet, and we will improve our models as we learn more. Write down each question you have about sea level rise on an individual sticky note. Followed by gallery walk and facilitated class discussion about questions we want to answer about sea level rise.
Lesson 6: Students revise their models and present them to the class and/or have a gallery walk. Students then update their models based on what they have heard from their classmates. Groups of 2-4 students.	Materials: UGC Earth Scene, dry erase markers. Relevant UGC Icons that can be printed, introduced, and incorporated into the models (optional): Water cycle, Precipitation, Clouds, Snow and ice cover, Sea level rise. Practices: Whole class share out/ Gallery Walk
Lesson 11 Students will use the online interactive to construct models, focusing on writing evidence based	Materials: Understanding Global Change Interactive https://www.biointeractive.org/classroom-resources/understanding-global-change

explanations for the connections in the model. Students will share models with other group members, read each of their connection statements aloud, and revise their models based on peer feedback. Students will model their ideas in pairs to receive feedback on the model from other groups members.	Relevant UGC Icons: Water cycle (precipitation, Snow and ice cover), Sea level rise, Air temperature, Greenhouse effect, Re-radiation of heat, Absorption/reflection of sunlight Greenhouse gases, Burning fossil fuels, Agricultural activities, Deforestation, Photosynthesis, Pollutants and waste, Renewable energy.
Lesson 17 Before the summative task, students individually or in groups to construct/revise their final models. Use the UGC Interactive to allow students to digitally represent their models and explain all connections in detail. Can be submitted digitally using PowerPoint Slides.	Materials: Understanding Global Change Interactive https://www.biointeractive.org/classroom-resources/understanding-global-change Relevant UGC Icons: Water cycle (precipitation, Snow and ice cover), Sea level rise, Air temperature, Greenhouse effect, Re-radiation of heat, Absorption/reflection of sunlight Greenhouse gases, Burning fossil fuels, Agricultural activities, Deforestation, Photosynthesis, Pollutants and waste, Renewable energy, Water temperature, Displacement of human populations, Habitat restoration (which involves Sedimentation, Productivity and biomass).

STEP 4. Select and sequence instructional resources to help students coherently build an understanding of the phenomenon

Below is a sequence learning experiences about sea level rise designed based on the progression of ideas in the explanation of the phenomenon from **STEP 2**, and the Earth System models from **STEP 3**. Students can use the **Activity Table** to keep track of how each resource provides information that enhances their understanding of sea level rise as the unit progresses.

If you are looking for additional resources, including activities, videos, and datasets to supplement this unit, we recommend visiting the following websites:

- **The Climate Literacy and Energy Awareness Network** (cleanet.org). The National Science Foundation and NOAA funded CLEAN collection houses over 700 free, high-quality teaching and learning resources about climate and energy that have been carefully vetted by scientists and educators.
- **Howard Hughes Medical Institute BioInteractive** (www.biointeractive.org/). BioInteractive resources are free, are developed by scientists and educators, and explore current scientific research.
- **NOAA Climate.gov** (climate.gov). This website provides current climate news, data, maps, and tips for teaching climate change.

STEP 4. Sea Level Rise Unit Planning Table

Lesson 1: How and why are sea levels changing? **Engaging with the phenomenon and constructing an initial model.** **I. Activity/resource/ dataset (website link):**	Deck 1, Slides 1-11 Use images, maps, graphs from: - Sea Level Trends, NOAA https://tidesandcurrents.noaa.gov/sltrends/sltrends.html (zoom in on map to focus on regional changes) - U.S. Sea Level Trend Map, NOAA https://tidesandcurrents.noaa.gov/sltrends/slrmap.html - Climate Change: Global Sea Level, NOAA Climate.gov https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level - Background on measuring sea level - NOAA Data in the Classroom: Understanding Sea Level https://dataintheclassroom.noaa.gov/content/sea-level - CLEAN Link https://cleanet.org/resources/47843.html
II. Investigative question(s) related to the anchoring phenomenon; the science practices students will engage in to answer the question (such as NGSS SEPs and scientific inquiry skills):	How and why are sea levels changing? SEPs: Analyzing and Interpreting Data, Asking Questions, Developing Models, Constructing Explanations
III. Key concepts students will explore and figure out (NGSS/ standards connections):	Students will: - Observe different places in the world where sea levels are rising. - Analyze and interpret graphs showing how much sea levels are changing around the world. - Construct their initial models explaining how/why sea levels are changing. - Pose initial ideas and questions about the mechanisms for sea level rise. Students figure out: Sea levels are changing around the world, in most places seas levels are rising, but different coastal locations are experiencing different rates of sea level rise.
IV. UGC topic connections students will make to explain the phenomenon:	Sea level rise is a global phenomenon and has/will impact human populations locally and around the world. Students might start to make some of the UGC connections in their initial models, but they will be explored in subsequent activities.

V. Materials, Instructions, Scaffolds, & Formative Assessment Ideas	Materials: Chart paper or UGC Earth Scene 11x17 or 18x24 color or black and white posters (1 per group), dry erase markers (if using laminated Earth scene posters), sticky notes. The components of the Earth scene can help prompt student thinking about parts of the Earth system and reduce the amount of drawing necessary to express those ideas. Instructions from slides 6-11: Use your ideas about how and why sea levels are rising to construct a model using words, diagrams, and arrows what you can **see** and what you think might be happening that you **can't see**. There are many ways to communicate your ideas. The purpose of this model is just to get your first ideas out on paper. We don't expect to have correct answers yet, and we will improve our models as we learn more. Write down each question you have about sea level rise on an individual sticky note. Model construction can be followed by a gallery walk and facilitated class discussion about questions we want to answer about sea level rise. The teacher might pose questions now or experiences later to prompt students to think about additional questions needed to fully understand phenomenon. Teachers can use students' questions to frame the purpose of subsequent activities. NOAA Data in the Classroom: Understanding Sea Level, Levels 1-3 can be used to explore how sea level is measured and tides. This resource can be used as homework for Lesson 1 or at the beginning of Lesson 2. Formative Assessment: Collect student models and questions in order to determine the range of prior knowledge in the classroom. Model can be used as an exit ticket.
VI. Time:	**50 (for modeling)-100 (if also using NOAA Data in the Classroom module) min**

Lesson 2: **Sources of water** **I. Activity/resource/ dataset (website link):**	Deck 1, Slides 12-17 World map (in materials folder) Water, water everywhere (NOAA, National Weather Service) https://www.weather.gov/jetstream/ll_water CLEAN Link: https://www.weather.gov/jetstream/ll_water
II. Investigative question(s) related to the anchoring phenomenon; the science practices students will engage in to answer the	What is/are the source(s) of water that are contributing to changes in sea level? How is water distributed in different places on Earth? (Related question: Does the amount of water on Earth increase or decrease through time? Or does water just move between different places?) SEPs: Analyzing and Interpreting Data, Constructing Explanations, Arguing from Evidence

question (such as NGSS SEPs and scientific inquiry skills):	
III. Key concepts students will explore and figure out (NGSS/ standards connections):	For sea levels to rise, water is entering the ocean from another reservoir. Students pose their initial ideas about the sources of water that could contribute to sea level rise. Students figure out using evidence from the activity that the only plausible source of water for sea level rise is ice, as the majority of water that is not in the oceans is locked up in ice.
IV. UGC topic connections students will make to explain the phenomenon:	The atmosphere, hydrosphere, and geosphere all contain significant water reservoirs. The biosphere is not included in the model because it is even smaller than the other reservoirs. Glaciers and ice caps (Snow and ice cover) contain most of the water that is not in the ocean.
V. Materials, Instructions, Scaffolds, & Formative Assessment Ideas	Materials: Copies of world map, water, food coloring (to make water drops easier to see), 8 beakers or plastic tubs, pipet or dropper, sticky notes. Students will first mark on the world map potential locations of sources of water that might contribute to sea level rise. They can do this individually or in pairs. Then they will compare their ideas to the Water, water everywhere model. It is suggested that you set up the Water, water everywhere model of water reservoirs as shown in slide 14 with sticky notes below each tub of water. Ask students to match the relative water volume in each container to the list of reservoirs (Atmosphere, Glaciers & icecaps, Groundwater and Aquifers, Rivers, Oceans, Freshwater lakes, Inland (salty) seas, Soil moisture). Students can individually or in groups write their guesses about which tub of water represents each reservoir on the sticky notes. You might need to explain what aquifers and inland salty seas are and where they are found. Formative assessment/ exit ticket idea: Were you surprised by what we learned about where water is distributed on Earth?
VI. Time:	**50 min**

Lesson 3: What's happening to ice around the world? **I. Activity/resource/ dataset (website link):**	Deck 1, Slides 18-29 If the largest water reservoir outside of the oceans is ice, is might be the source of water contributing to sea level rise. Now students will examine where ice is found and interpret datasets to understand how ice cover is changing around the world. Data Sources: - 2013 State of the climate: Mountain glaciers, NOAA Climate.gov https://www.climate.gov/news-features/understanding-climate/2013-state-climate-mountain-glaciers-0 - Happening Now: Arctic Sea Ice Sets Record Low, NOAA https://oceantoday.noaa.gov/happennowarcticseaice/ - Glacier Monitoring, Kenai Fjords National Park https://www.nps.gov/kefj/learn/nature/glaciermonitoring.htm - Arctic Glacier Mass Balance, GlobalChange.gov https://www.globalchange.gov/browse/indicators/arctic-glacier-mass-balance - Unprecedented Arctic warmth in 2016 triggers massive decline in sea ice, snow, NOAA http://www.noaa.gov/media-release/unprecedented-arctic-warmth-in-2016-triggers-massive-decline-in-sea-ice-snow - Arctic Sea Ice Is Losing Its Bulwark https://earthobservatory.nasa.gov/images/89038/arctic-sea-ice-is-losing-its-bulwark
II. Investigative question(s) related to the anchoring phenomenon; the science practices students will engage in to answer the question (such as NGSS SEPs and scientific inquiry skills):	What's happening to ice around the world? SEPs: Analyzing and Interpreting Data, Constructing Explanations
III. Key concepts students will explore and figure out (NGSS/ standards connections):	Sea ice and land ice are melting at a faster than at recent historical rates. The melting of glaciers, ice caps, and sea ice (Snow and ice cover) is a global phenomenon.
IV. UGC topic connections students will make to explain the phenomenon:	The melting of glaciers, ice caps, and sea ice (Snow and ice cover) is a global phenomenon that could be contributing to sea level rise.
V. Materials, Instructions, Scaffolds, & Formative Assessment Ideas	Materials: Printed copies of the graphs and images from slides 23-28. Show students images of ice on land and ice in the ocean (slides 19-21). Ask students, "Where do we find ice?" Reponses might include at the poles and in the mountains. Explain that there are expected seasonal changes in in snow and ice over

	as we go from winter to summer, but that we can also look and more long-term patterns of change. Distribute images from links above (slides 23-28 and ask (instructions from slide 22): How does each image contribute to our understanding of the mechanism for sea level rise? 1. In groups of 2-4, analyze and interpret the observations or data found in each image. 2. Record your interpretations on the images. <u>Formative Assessment ideas:</u> Have students answer the investigation question, "What's happening to ice around the world?" or ask students what additional questions they have about sea and land ice.
VI. Time:	**50 min**

<u>Lesson 4: How does water move?</u> I. Activity/resource/ dataset (website link):	Deck 1, Slides 30-38 What-a-cycle (NOAA, National Weather Service) https://www.weather.gov/jetstream/ll_whatacycle CLEAN Link https://cleanet.org/resources/44660.html
II. Investigative question(s) related to the anchoring phenomenon; the science practices students will engage in to answer the question (such as NGSS SEPs and scientific inquiry skills):	How do glaciers form and melt? Are there differences in how sea and land ice melt contribute to sea level rise? Where does the water from melted ice go? SEPs: Constructing Explanations
III. Key concepts students will explore and figure out (NGSS/ standards connections):	Water often does not stay in one place, it moves from one place to another. Water can enter glaciers as snow. When glaciers melt, water moves into the ocean through rivers and streams. Water cycle is not just phase changes in water. It also includes the movement of water from one place to another.

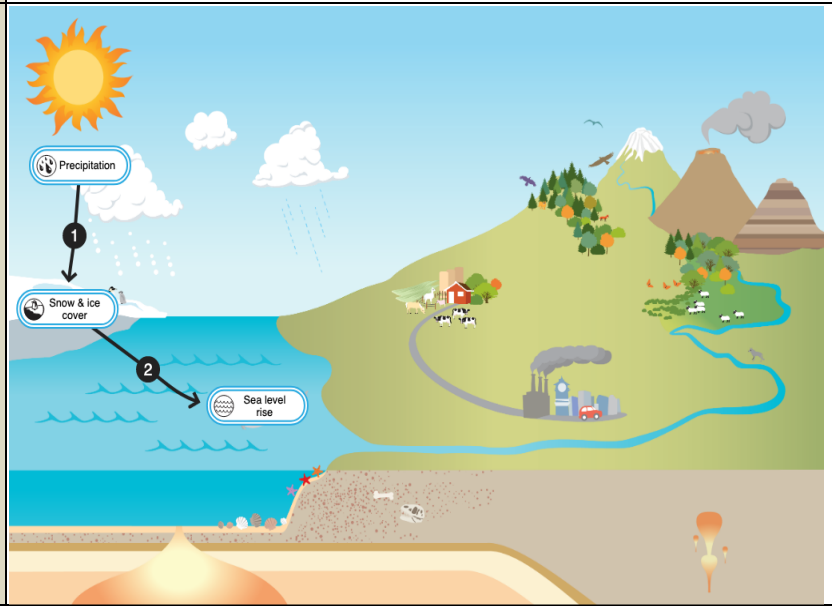
IV. UGC topic connections students will make to explain the phenomenon:	**Water cycles** as it transforms between a solid, liquid, and gas due to energy from **solar radiation** and **re-radiated heat**. **Clouds**, water vapor, **precipitation, and snow and ice cover** are all parts of the **water cycle**.
V. Materials, Instructions, Scaffolds, & Formative Assessment Ideas	Materials: Black and white Earth scene for water cycle models, pencils, dice (at least 9, one for each station, but ideally have 2-3 at each station, especially at the atmosphere and ocean stations), copy of cards from What-a-cycle game, sticky notes. Use slides 31-32 to explain that we will make a model of the water cycle (now including plants). Instructions from slide 33: 1. Half of participants go to the 'Oceans' station. Evenly distribute the remaining participants across the other stations except for the 'plants' station. 2. Label your position where you start on your Earth scene as #1. 3. Roll the dice and turnover the card that corresponds to that number. 4. If the card says to move, move to the new location. - **When you arrive at the station, put a tally mark on the station post-it. If your card says to stay at that station, place a new tally mark.** - On your worksheet, draw an arrow from your starting location to the new position. Label the new position #2. 5. Roll the dice at your station and repeat steps 3 & 4 until told to stop. Allow students to move to the stations for around 8-10 minutes, at most. Have students discuss (slide 34) : - How are you models similar or different? - How does snow and ice form? - How does the water from ice get to the ocean? - How could water movement be related to changes in sea level? As they discuss their models, you can post the total number of visits tallied at each station on Earth scene slide 35 (slide has example numbers). Lead a class discussion to answer the question: How do these data help us understand how water moves and contributes to sea level rise? What can our water cycle models not explain? Students can talk in groups before sharing with the class.

	Answers could include (and use activity link as reference): - There are not enough people in the class to represent how water is distributed in Earth (example of how 100,000 participants would be distributed in the What-a-cycle model is on slide 36). - The model does not explain how long water stays in different places (residence time, slide 37). Read What-a-cycle instructions for more information. Formative Assessment/ exit ticket idea: Have students answer the investigation question, "How do these data help us understand how water moves and contributes to sea level rise?"
VI. Time:	**50 min**

Lesson 5: Does land ice or sea ice contribute to sea level rise? **I. Activity/resource/ dataset (website link):**	Deck 1, Slides 39-43 Students model the melting of land and sea ice to land ice, sea ice, or both contribute to sea level rise. Global Climate Change and Sea Level Rise (California Academy of Sciences) http://www.calacademy.org/educators/lesson-plans/global-climate-change-and-sea-level-rise CLEAN Link https://cleanet.org/resources/41835.html
II. Investigative question(s) related to the anchoring phenomenon; the science practices students will engage in to answer the question (such as NGSS SEPs and scientific inquiry skills):	Are there differences in how sea and land ice melt contribute to sea level rise? SEPs: Planning and Carrying Out Investigations, Analyzing and Interpreting Data, Constructing Explanations
III. Key concepts students will explore and figure out (NGSS/ standards connections):	Land ice contributes to sea level rise because the ocean levels increased when land ice melted, but not when the sea level ice melted. Because sea ice is floating in the ocean, the sea level does not rise because it does not displace additional volumes of water. In contrast, land ice melts because the ice was not originally in the ocean.
IV. UGC topic connections students will make to explain the phenomenon:	Decreased to **snow & ice cover** on land results in sea level rise.

V. Materials, Instructions, Scaffolds, & Formative Assessment Ideas	Materials: Plastic tubs (large enough for ice to float in), modeling clay, ruler and markers, water, ice, Activity table handouts (one per person). This activity can be done as either guided inquiry, where you present the question (Does the melting of land and/or sea ice contribute to sea level rise?) and students figure out how to design an experiment with materials provided and collect data and answer the question, OR as structured inquiry using procedures provided in the Cal Academy activity. You will want to use small pieces of ice so it doesn't take all class period to see changes in the water levels in the experiment. If students are waiting for ice to melt, you can have them start their Earth system models for Lesson 6. NOTE: When you are making a model of sea ice, remember that sea ice FLOATS and should not touch the bottom of the tub at all. As students are waiting for ice to melt, they can work on filling out the activity table in groups, or through a class discussion (slide 42). Formative Assessment/ exit ticket: Have students answer the following question, "Are there differences in how sea and land ice melt contribute to sea level rise? Support your answer with data."
VI. Time:	**50 min**

<u>Lesson 6: Sea level rise model revision</u> I. Activity/resource/ dataset (website link):	Deck 1, Slides 44-48 Students revise their Earth system models based on what they have learned in Lessons 1-5.
II. Investigative question(s) related to the anchoring phenomenon; the science practices students will engage in to answer the question (such as NGSS SEPs and scientific inquiry skills):	SEPs: Developing models, Constructing explanations
III. Key concepts students will explore and figure out (NGSS/ standards connections):	No new concepts are introduced during the model revision.

IV. UGC topic connections students will make to explain the phenomenon:	Water cycle (precipitation), Snow and ice cover, Sea level rise
V. Materials, Instructions, Scaffolds, & Formative Assessment Ideas	Materials: Activity table handouts (one per person), Initial models on UGC Earth Scene, dry erase markers (if using laminated Earth scene posters), sticky notes. Relevant UGC Icons that can be printed, introduced, and incorporated into the models (optional): Water cycle, Precipitation, Clouds, Snow and ice cover, Sea level rise. To prepare students revise their models: - Students revise maps to show locations of land ice. - Teacher can lead a discussion to fill in the Activity Table (slide 47 and in materials folder). Evidence in the Activity table can be used as a checklist of concepts/ connections among ideas that should be in the model. Students revise their initial sea level rise models in groups. Students present their models to the class and/or have a gallery walk. Students then update their models based on what they have heard from their classmates. Formative assessment ideas/ exit ticket: What questions do you have about how and why sea levels are rising?
VI. Time:	**50 min**
VII. Lesson 6 Example Earth system model	 Note: Student models will likely include other components/ ideas, but these are the connections that have been established based on evidence from Lessons 1-5.

Lesson 7: What's really warming the world? **I. Activity/resource/ dataset (website link):**	Deck 1, Slides 49-54 "What's really warming the world?" graphs of NASA datasets https://www.bloomberg.com/graphics/2015-whats-warming-the-world/ CLEAN Link: https://cleanet.org/resources/51236.html
II. Investigative question(s) related to the anchoring phenomenon; the science practices students will engage in to answer the question (such as NGSS SEPs and scientific inquiry skills):	In Lesson 3, students explored datasets that indicate that land (and sea) ice is melting. What might be causing the ice to melt at a faster than historical rate? SEPs: Analyzing and Interpreting Data, Constructing Explanations
III. Key concepts students will explore and figure out (NGSS/ standards connections):	Since the industrial age, greenhouse gases have increased significantly, and this is the only human or non-human process that could cause warming at the observed rate.
IV. UGC topic connections students will make to explain the phenomenon:	Non-human processes (Earth's tilt and orbit, volcanoes, the Sun) do NOT explain the increase in Earth's average temperature. Human activities that increase greenhouse gases in the atmosphere contribute to increases in global temperature, which then causes ice melt.
V. Materials, Instructions, Scaffolds, & Formative Assessment Ideas	Materials: Printed copies of "What's really warming the world?" graphs (in materials folder, one set for each group), What's Really Warming the World Table (in materials folder) for documenting interpretations of graphs (one for each student). Students fill out chart to discuss how various factors influence Earth's average temperature (slide 52). Each group of 4 students receives the graphs, and analyze and interpret "What do these data indicate?" and "What do these data mean?" in relationship to sea level rise and fill out chart (slide 54). Students can alternatively, or in addition to interpreting all the graphs, become "experts" in on one or two of the graphs. Then students can jigsaw and share what they learned from their graphs with other groups and rotate around the room. Formative assessment/ exit ticket: Which graph was the most interesting to you or had the most surprising data?
VI. Time:	**50 min**

Lesson 8: How global warming works **I. Activity/resource/ dataset (website link):**	Deck 1, Slides 55-62 How greenhouse gases work: How Global Warming Works Video (UC Berkeley)http://www.howglobalwarmingworks.org/ CLEAN Link: https://cleanet.org/resources/56031.html It's Us Video: https://www.youtube.com/watch?v=-PrrTk6DqzE&t=13s CLEAN Link: https://cleanet.org/resources/42867.html
II. Investigative question(s) related to the anchoring phenomenon; the science practices students will engage in to answer the question (such as NGSS SEPs and scientific inquiry skills):	How do increases in greenhouse gas emissions lead to increased global temperatures? What are the primary sources for increased greenhouse gas emissions that affect sea level rise? What are the ways I contribute to greenhouse gas emissions? SEPs: Constructing Explanations
III. Key concepts students will explore and figure out (NGSS/ standards connections):	Student's figure out: From How Global Warming Works: The greenhouse effect happens when greenhouse gases re-radiate heat in the atmosphere, impeding the loss of heat, which increases the temperature of the Earth's atmosphere. When solar radiation reaches the Earth, light is absorbed or reflected. When light is absorbed, it is reradiated as heat. Human activities have increased greenhouse gases in the atmosphere. From It's Us: Sources of greenhouse gases have different isotopic signatures. The type of carbon that has increased in the atmosphere since the industrial revolution indicates that humans burning fossil fuels are the major source of carbon dioxide.
IV. UGC topic connections students will make to explain the phenomenon:	The light that is absorbed is also reradiated as heat from the surface of the Earth (the Earth emits infrared light) Greenhouse gases in the atmosphere, such as methane and carbon dioxide, let visible light pass through, but absorb and re-radiate heat. When greenhouse gases radiate heat this creates the greenhouse effect. The greenhouse effect slows the loss of heat from the Earth to space, causing an increase in air temperature. The greenhouse effect slows the loss of heat from the Earth to space, causing an increase in air temperature.

V. Materials, Instructions, Scaffolds, & Formative Assessment Ideas	Materials: Access to online videos, printed copies of transcript of 5-minute How Global Warming Works video, Activity table. Watch the 5-minute video version on the How Global Warming Works a couple times with your students. Provide students with copies of the printed transcript so they can underline or circle ideas that are new or useful for explaining how greenhouse gases work. Have students write answers to guiding questions on the slides, or use these as discussion questions. Show the It's Us video and answer the question, "How do we know greenhouse gases are increasing from human activities." Have students analyze and interpret the EPA Global and U.S. Greenhouse Gas Emissions graphs and answer the questions on the slides. Students complete the Carbon Calculator activity. Formative Assessment/ exit ticket: Students answer the question "How does increasing greenhouses gases in the atmosphere due to human activities increase average global temperatures?"
VI. Time:	**50 min**

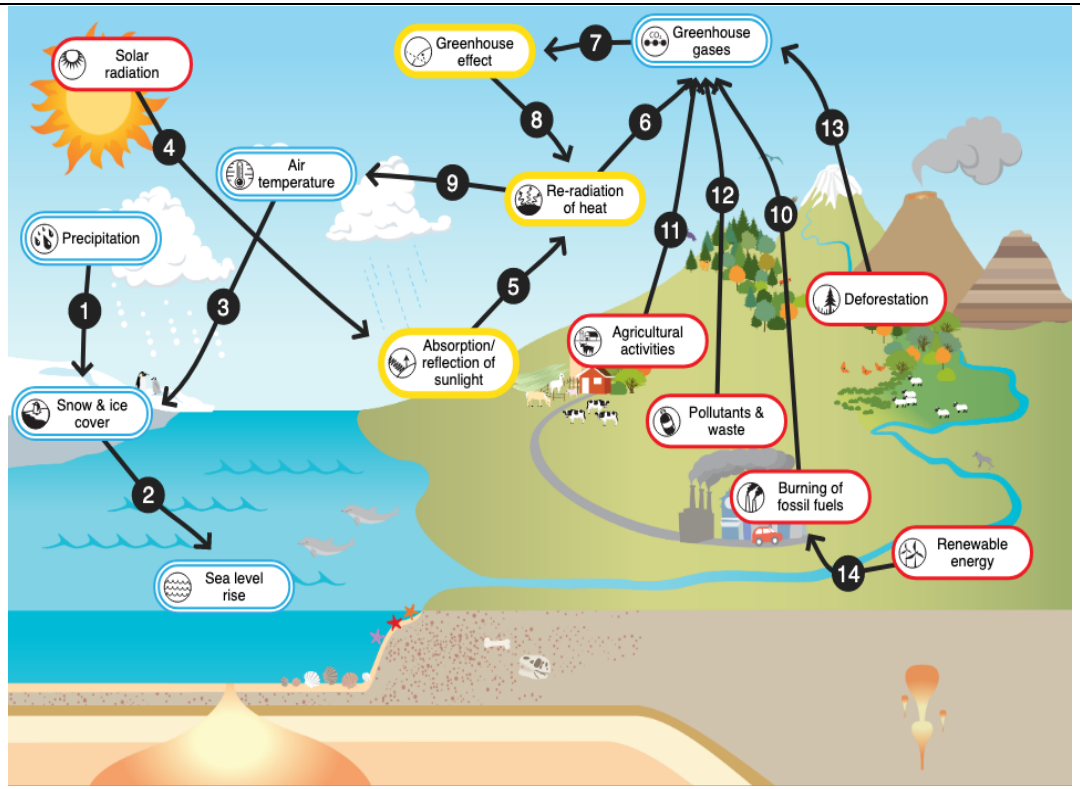
Lesson 9: Sources of greenhouse gases **I. Activity/resource/ dataset (website link):**	Deck 1, Slides 63-70 Climate Change: How Do We Know? NASA https://climate.nasa.gov/evidence/ Exploring sources of greenhouse gases: Climate Change Indicators: Global Greenhouse Gas Emissions, EPA https://www.epa.gov/climate-indicators/climate-change-indicators-global-greenhouse-gas-emissions Climate Change Indicators: U.S. Greenhouse Gas Emissions, EPA https://www.epa.gov/climate-indicators/climate-change-indicators-us-greenhouse-gas-emissions Carbon Calculator Activity https://eli.lehigh.edu/climate-change/instructional-sequence/day-16 CLEAN Link https://cleanet.org/resources/43396.html (Potential extension) Climate change food calculator: What's your diet's carbon footprint? https://www.bbc.com/news/science-environment-46459714
II. Investigative question(s) related to the anchoring phenomenon; the science practices students will engage	How do increases in greenhouse gas emissions lead to increased global temperatures? What are the primary sources for increased greenhouse gas emissions that affect sea level rise? What are the ways I contribute to greenhouse gas emissions?

in to answer the question (such as NGSS SEPs and scientific inquiry skills):	SEPs: Analyzing and Interpreting Data, Constructing Explanations
III. Key concepts students will explore and figure out (NGSS/ standards connections):	Greenhouse gases are released from burning fossil fuels, agricultural activities, pollutants and waste from industry, and land use/ deforestation. Daily choices we make can affect how much greenhouse gases to the atmosphere.
IV. UGC topic connections students will make to explain the phenomenon:	Human activities, including burning fossil fuels, agricultural activities, certain pollutants and waste, and deforestation all release the greenhouse gas in the atmosphere, enhancing the greenhouse effect. This change increases temperature that melt ice around the world, leading to global sea level rise
V. Materials, Instructions, Scaffolds, & Formative Assessment Ideas	Materials: Access to online carbon calculator, printed copies of the Global and U.S. Greenhouse Gas Emissions graphs, Activity table. Show students Slide X that shows that carbon dioxide levels have not been this high since at least 800,000 years ago. The discussion and interpretation of this graph as a class or in groups could definitely be extended as students note the cyclic pattern and ask questions about what Earth was like in the past. Here are some additional resources: Graphic: Carbon dioxide hits new high, NASA https://climate.nasa.gov/climate_resources/7/graphic-carbon-dioxide-hits-new-high/ How the World Passed a Carbon Threshold and Why It Matters, Yale Environment 360 https://e360.yale.edu/features/how-the-world-passed-a-carbon-threshold-400ppm-and-why-it-matters Have students analyze and interpret the EPA Global and U.S. Greenhouse Gas Emissions graphs and answer the questions on the slides. Students complete the Carbon Calculator activity. Formative Assessment: Students turn in the carbon footprint plan and answer the questions "What's one thing I can do this week to reduce my carbon footprint? How do greenhouse gas emissions affect sea level rise?", or complete the questions as homework.
VI. Time:	**50 min**

Lesson 10: Introduction to the Understanding Global Change Infographic **I. Activity/resource/ dataset (website link):**	Deck 2, Slides 2-33 Introduction of Understanding Global Change Infographic https://cleanet.org/clean/literacy/tools/UGC/infographic.html Understanding Global Change Interactive https://www.biointeractive.org/classroom-resources/understanding-global-change
II. Investigative question(s) related to the anchoring phenomenon; the science practices students will engage in to answer the question (such as NGSS SEPs and scientific inquiry skills):	How can we organize all the components of the Earth system related to sea level rise and climate change? How can we identifying other Earth system phenomena and processes that will help us better understand the causes and consequences of sea level rise? SEPs: Developing and using models
III. Key concepts students will explore and figure out (NGSS/ standards connections):	No new concepts related to sea level rise will be introduced, but students will learn to organize their ideas using the structure of the UGC Framework (Causes of Global Change, How the Earth System works – atmosphere, hydrosphere, biosphere, geosphere, and Measurable Changes in the Earth System). Students figure out that there are various components of the Earth system that are connected and related to sea level rise. To understand global changes requires connecting components from all three categories of the UGC infographic. The process of calling out these components helps clarify and make explicit what parts of the Earth are related to sea level rise (or other global change phenomenon).
IV. UGC topic connections students will make to explain the phenomenon:	Topic connections from all previous lessons, no new connections.
V. Materials, Instructions, Scaffolds, & Formative Assessment Ideas	Materials: Two colors of sticky dots (ideally red and blue), copies of the simple, with spheres Understanding Global Change Infographic, copies of the complex Understanding Global Change Infographic, copies of UGC icons, large UGC icons (in materials folder), large wall poster of simple, with spheres Understanding Global Change Infographic (optional), access to the online UGC interactive

	Students work in groups of 2-3 to identify and tag with sticky dots the components of their sea level rise models that fall into these two categories: - Causes of Change in the Earth System (reasons why the Earth system is changing) – red dots - Measurable Changes in the Earth System (data that are evidence of change) – blue dots Discuss what are the components of the models tagged in each category. Then introduce the simple (with spheres) Understanding Global Change Infographic (Slides 6-7). Have students write the causes of change and measurable changes they identified in their model into the appropriate sections of the framework. Next, step through building up the complex version of the infographic, starting with How the Earth system works. Have students follow along and fill in the concepts they think are relevant to sea level rise (these are the absorption/reflection of sunlight, re-radiation of heat, water cycle, and greenhouse effect icons). Next talk about causes of change and measurable changes (slides 8-32). Formative assessment/ exit ticket: Identify which icons/ topics in the UGC Infographic are represented in your sea level rise models. Are there other icons/ topics you might consider adding to your model? Have students (instructions from slide 33): - Read the introduction and explore the interactive framework by zooming in and out and clicking on the icons and words. - Identify which icons/ topics in the UGC Infographic are represented in your sea level rise models. Are there other icons/ topics you might consider adding to your model? Alternatively, a list of the necessary components could be provided and students just identify 1-2 additional icons they think are connected to sea level rise.
VI. Time:	**50 min**

Lesson 11: Sea Level Rise Model Revisions using the UGC Interactive **I. Activity/resource/ dataset (website link):**	Deck 2, Slides 34-42 Understanding Global Change Interactive https://www.biointeractive.org/classroom-resources/understanding-global-change
II. Investigative question(s) related to the anchoring phenomenon; the science practices students will engage in to answer the question (such as NGSS SEPs and scientific inquiry skills):	How and why are sea levels changing? SEPs: Developing models, Constructing explanations
III. Key concepts students will explore and figure out (NGSS/ standards connections):	SEPs: Developing models, Constructing explanations, Obtaining, Evaluating, and Communicating Information
IV. UGC topic connections students will make to explain the phenomenon:	Topic connections from all previous lessons, no new connections.
V. Materials, Instructions, Scaffolds, & Formative Assessment Ideas	Materials: Access to the online UGC interactive, handouts from Lesson 10 Students will use online interactive to construct models with evidence based explanations for all of the connections in the models. Students can work in groups of 2 and then exchange models with other members of their group members to compare their models. Remind students that there are many ways to express similar ideas. It is important to provide explanations with evidence for each connection they construct. Reading each of their connection statements aloud and receiving feedback can help students revise their explanations to be clear and accurate. Formative assessment/ exit ticket: Have students save and export as a PowerPoint to save to a Google Drive or on their computers. Additionally, students could try to add 1-2 additional icons they think are connected to sea level rise. If students do not complete their models, they can continue to work on them as homework.
VI. Time:	**50 min**

VII. Lesson 11 Example Earth system model	

Lesson 12: How does a warming world affect the ocean? **I. Activity/resource/ dataset (website link):**	Deck 2, Slides 43-46 Thermal expansion of water (UCAR Center for Science Education): https://scied.ucar.edu/activity/thermal-expansion-water CLEAN Link: https://cleanet.org/resources/43392.html
II. Investigative question(s) related to the anchoring phenomenon; the science practices students will engage in to answer the question	Aside from ice melting, what else could explain the observed rise in sea level? Why is the temperature of the ocean rising? What happens to seawater when the temperature of the ocean rises? What properties of water create the phenomenon of thermal expansion? SEP's: Asking Questions, Carrying out Investigations, Analyzing and Interpreting Data

(such as NGSS SEPs and scientific inquiry skills):	
III. Key concepts students will explore and figure out (NGSS/ standards connections):	Students analyze graphs of sea surface temperatures and sea level rise that illustrates that ice melting cannot fully explain changes in sea levels. Students consider alternative causes for observed increases in sea level. Students complete an experiment to investigate thermal expansion.
IV. UGC topic connections students will make to explain the phenomenon:	As the average global **temperature** of the atmosphere and ocean rise, thermal expansion of water will also contribute to sea level (rise) changes.
V. Materials, Instructions, Scaffolds, & Formative Assessment Ideas	Materials: List provided in activity. Complete the demonstration. Possible extension: Explore specific heat capacity of water. Formative Assessment:/ exit ticket: Create a model using drawings and words to show what happens to water molecules as sea surface temperatures increase due to global warming. Include in your diagram the source of the heat causing water temperatures to increase.
VI. Time:	**50 min**

Lesson 13: Sea level rise projections **I. Activity/resource/ dataset (website link):**	Deck 2, Slides 47-50 Sea Level Rise Viewer (NOAA) https://coast.noaa.gov/digitalcoast/tools/slr Sea Level Rise Viewer Tutorial: https://coast.noaa.gov/digitalcoast/training/slr-tutorial.html It is recommended that you complete the tutorial and become familiar with the viewer before class. CLEAN Link https://cleanet.org/resources/51299.html Is Sea Level Rising (NOAA) https://oceanservice.noaa.gov/facts/sealevel.html
II. Investigative question(s) related to the anchoring phenomenon; the science practices students will engage in to answer the question	How much is sea level expected to rise in the next 30-100 years? What parts of my city/ coastline will be most affected? SEPs: Analyzing and Interpreting Data

(such as NGSS SEPs and scientific inquiry skills):	
III. Key concepts students will explore and figure out (NGSS/ standards connections):	Students figure out that regions around the bay and topographic lows will be more affected by sea level rise in the next 30-100 years. Urbanized areas will be affected by sea level rise and cause displacement of human populations in coastal regions.
IV. UGC topic connections students will make to explain the phenomenon:	Human populations will be displaced due to sea level rise.
V. Materials, Instructions, Scaffolds, & Formative Assessment Ideas	Materials: Online access to Sea Level Rise Viewer, NOAA article Students use Sea Level Rise Viewer (NOAA) to identify areas that might be susceptible to sea level rise, and examine maps showing projected sea level rises in your region (maps of San Francisco Bay Area are provided in the slide deck). Students read about the difference between global and local sea level rise, storm surges and flooding. Formative Assessment/ exit ticket: students answer investigation questions.
VI. Time:	**50 min**

Lesson 14: Mitigating climate change and adapting to sea level rise in the San Francisco Bay Area (adaptable for other regions) **I. Activity/resource/ dataset (website link):**	Deck 51-54 Bay Area Sea Level Rise Links and Resources (in materials folder) Note: This activity will require modification that you find other reading materials if students will be investigating regions other than the San Francisco Bay Area. Climate Change Adaptation and Mitigation, PBS Learning Media https://www.pbslearningmedia.org/resource/ecb10.sci.ess.watcyc.adaptation/climate-change-adaptation-and-mitigation/ CLEAN Link https://cleanet.org/resources/43823.html
II. Investigative question(s) related to the anchoring phenomenon; the science	What is the difference between adapting to climate change and mitigating climate change? How can communities be resilient and adapt to sea level rise? SEPs: Constructing Explanations, Engaging in Argument from Evidence, Obtaining, Evaluating, and Communicating

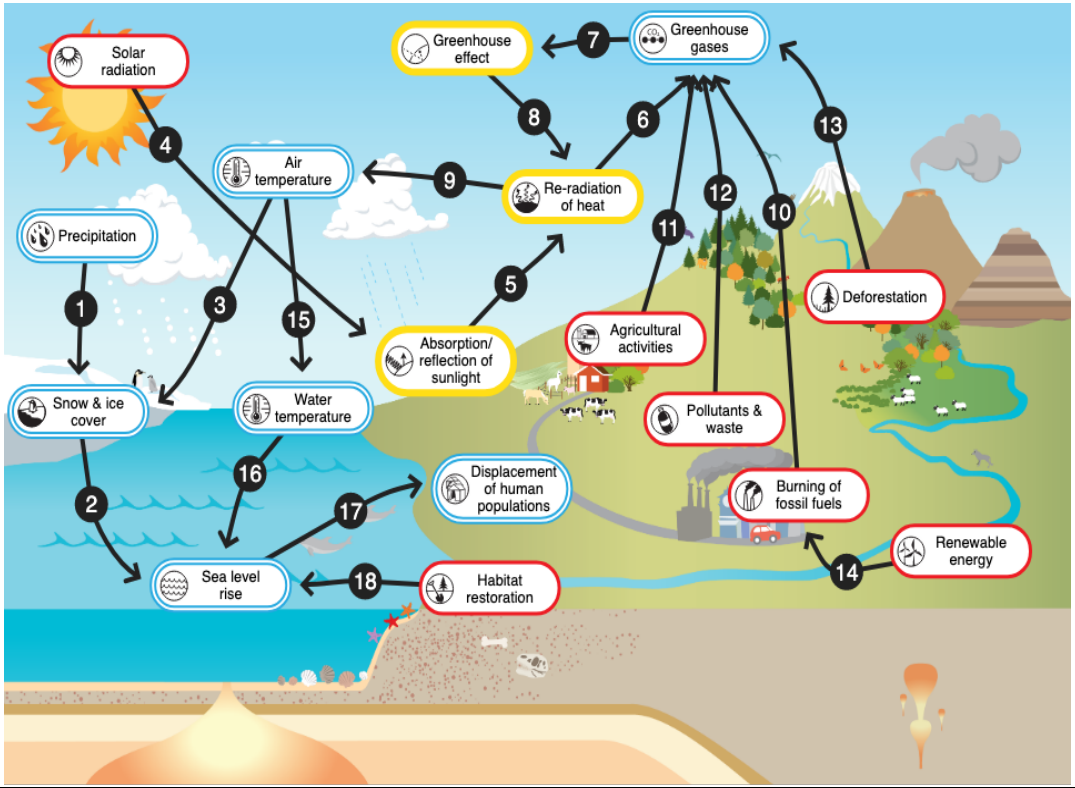
practices students will engage in to answer the question (such as NGSS SEPs and scientific inquiry skills):	Information
III. Key concepts students will explore and figure out (NGSS/ standards connections):	Students figure out that there are various proposals for adapting to sea level rise (sea walls, not building in flood zones, etc.) and that mitigation of climate change will reduce the rate and magnitude of sea level rise in the future.
IV. UGC topic connections students will make to explain the phenomenon:	Displacement of human populations, innovation, renewable energy, urbanization
V. Materials, Instructions, Scaffolds, & Formative Assessment Ideas	Materials: Access to online video, printed articles, poster paper, pens, sticky dots. Show students the Climate Change Adaptation and Mitigation, PBS Learning Media video. Discuss questions, "What is the difference between adapting to climate change and mitigating climate change? Why are both important?" Students could create small poster and present their ideas to the class. Divide reading materials (news articles, city plans) among groups and each reads about one mitigation or adaptation plan for the SF Bay Area (or your region). As students read, consider the questions: 1. Is this a mitigation or adaptation plan (or both)? Explain using drawings, words, and arrows. 2. How can we connect this idea to the sea level rise model? Hint: Refer to the Understanding Global Change Infographic and look for relevant topics/icons. Groups make a poster summarizing and assessing the strengths and limitations of the proposal they read about.Students share what they learned during a gallery walk and tag with sticky dots the idea they think is most likely to be useful/effective for adapting to sea level rise. As a class discuss which plans might be the best strategy while accounting for constraints (e.g., cannot move SF population inland), and how we could represent those ideas in our models.
VI. Time:	**50 min**

Lesson 15: Mitigating climate change and	Slides 55-62 Sea Level Rise in the San Francisco Bay – Considering Morphology in Adapting Management https://serc.carleton.edu/vignettes/collection/42858.html

adapting to sea level rise in the San Francisco Bay Area (adaptable for other regions) – Continued **I. Activity/resource/ dataset (website link):**	Sea Level Rise Viewer (NOAA) https://coast.noaa.gov/digitalcoast/tools/slr Sea Level Rise Viewer Marsh Migration Tutorial: https://coast.noaa.gov/elearning/marshmigration/ It is recommended that you complete the tutorial and become familiar with the viewer before class. CLEAN Link https://cleanet.org/resources/51299.html
II. Investigative question(s) related to the anchoring phenomenon; the science practices students will engage in to answer the question (such as NGSS SEPs and scientific inquiry skills):	How and why is tidal marsh habitat restoration useful for adapting to the effects of sea level rise? How will tidal marshes be impacted in my region by sea level rise?
III. Key concepts students will explore and figure out (NGSS/ standards connections):	Students figure out that tidal marshes reduce the risks of sea level rise because they absorb water and act as a physical barrier to rising sea levels. Students will see in the Sea Level Rise viewer that the location of marshes will change with sea level rise.
IV. UGC topic connections students will make to explain the phenomenon:	Habitat restoration (productivity and biomass, sedimentation) can buffer the effects of sea level rise and reduce the displacement of human populations.
V. Materials, Instructions, Scaffolds, & Formative Assessment Ideas	Materials: Printed article, online access to Sea Level Rise Viewer All students read Sea Level Rise in the San Francisco Bay – Considering Morphology in Adapting Management, if relevant to your region. You can also use the content in this reading and then apply the concepts to your local environment. Have students read an article or articles, and analyze/interpret maps of locations of tidal marsh habitats. Students explore how marshes in their region will change with sea level rise and propose areas that would most benefit from restoration efforts. Note: You will likely have to introduce the vocabulary in the map key (e.g., brackish/ transitional marsh, unconsolidated shore).

	Formative assessment/ exit ticket: Students turn in a proposal for where they think marshes should be restored based on maps of marshland and human populations.
VI. Time:	**50 min**

Lesson 16: Final Earth system model revision **I. Activity/resource/ dataset (website link):**	Slides 63-66 Introduction of Understanding Global Change Infographic https://cleanet.org/clean/literacy/tools/UGC/infographic.html Understanding Global Change Interactive https://www.biointeractive.org/classroom-resources/understanding-global-change
II. Investigative question(s) related to the anchoring phenomenon; the science practices students will engage in to answer the question (such as NGSS SEPs and scientific inquiry skills):	How and why are sea levels changing? How will sea level rise impact humans? How can communities mitigate and adapt to sea level rise? SEPs: Developing and using models, Constructing Explanations, Obtaining, Evaluating, and Communicating Information
III. Key concepts students will explore and figure out (NGSS/ standards connections):	Students will add ideas about mitigation of, and adaptation to sea level rise to their models.
IV. UGC topic connections students will make to explain the phenomenon:	Relevant icons include: Displacement of human populations, innovation, renewable energy, urbanization, habitat restoration, sedimentation, productivity and biomass
V. Materials, Instructions, Scaffolds, & Formative Assessment Ideas	Materials: Access to online UGC interactive or paper modeling materials, Activity table. Before the summative task, students individually fill out the activity table and construct/revise their final models. This final model could be completed in groups and then printed and shared through a gallery walk. Use the UGC Interactive to allow students to digitally represent their models and explain all connections in detail. Can be submitted digitally using PowerPoint Slides. Students could also work individually or in groups to construct the model and then write an in-class essay as a summative assessment (ideas in Lesson 17).

VI. Time:	**50 – 100 min**
VII. Lesson 16 Example Earth system model	

<u>Lesson 17: Summative Assessment</u> **I. Activity/resource/ dataset (website link):**	Slides 67-69 Introduction of Understanding Global Change Infographic https://cleanet.org/clean/literacy/tools/UGC/infographic.html Understanding Global Change Interactive https://www.biointeractive.org/classroom-resources/understanding-global-change
II. Investigative question(s) related to the anchoring phenomenon; the science practices students will engage in to answer the question	How and why are sea levels changing? How will sea level rise impact humans and how can communities respond to these changes? SEPs: Constructing Explanations, Engaging in Argument from Evidence, Developing and <u>using</u> models

(such as NGSS SEPs and scientific inquiry skills):	
III. Key concepts students will explore and figure out (NGSS/ standards connections):	No new concepts will be explored.
IV. UGC topic connections students will make to explain the phenomenon:	No new connections will be made during the assessment.
V. Materials, Instructions, Scaffolds, & Formative Assessment Ideas	Materials: Models constructed in Lesson 16, paper, or online template for written responses. Before the summative task, students individually or in groups to construct/revise their final models. Use the UGC Interactive to allow students to digitally represent their models and explain all connections in detail. Can be submitted digitally using PowerPoint Slides. Students construct an explanation using evidence gathered during the lesson sequence and their sea level rise models to answer the questions: How and why are sea levels changing? How will sea level rise impact humans? How can communities mitigate and adapt to sea level rise? Example writing scaffolds to support students in writing responses to the questions (Optional) Make a claim for each part of the question "Human have contributed to sea level rise by ....." Use evidence from lessons and reasoning to support this claim. Each piece of evidence used should have its own supporting reasoning. "Humans will be impacted by rising sea levels because ..... " Again, support with evidence and reasoning. "We can do ..... to mitigate and/or adapt to the effects of sea level rise" Again, support with evidence and reasoning. Additional writing scaffolds can be found on the Ambitious Science Teaching website: https://ambitiousscienceteaching.org/claim-evidence-reasoning-template-high-school/ An example summative assessment rubric can be found on the Ambitious Science Teaching website: https://ambitiousscienceteaching.org/claim-evidence-reasoning-template-high-school/

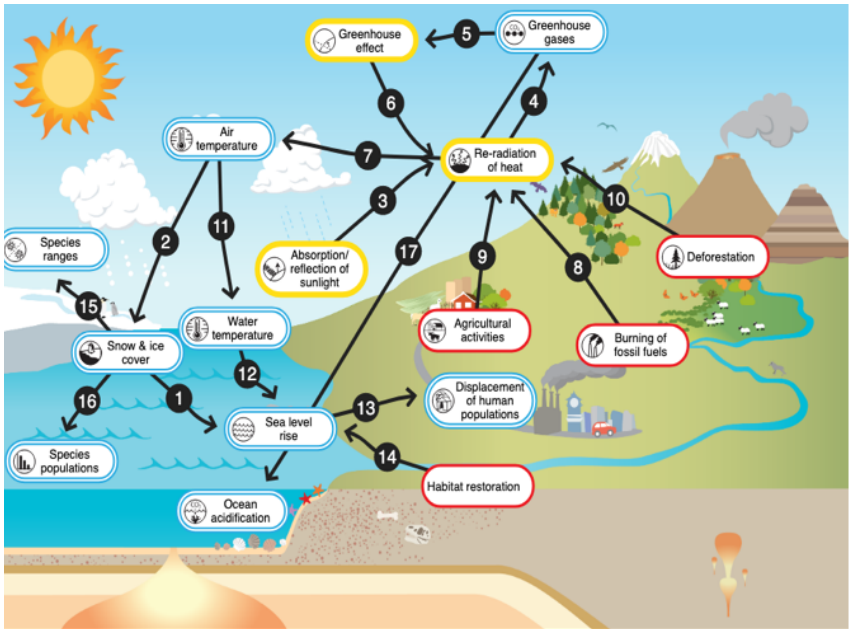
VI. Time:	50 – 100 min

STEP 5. Apply an Earth systems perspective and connect learning to other phenomena and units

The use of the Understanding Global Change Framework and Earth system modeling tools can extend beyond the Sea Level Rise Unit. These are practices that can be applied across the curriculum.

Ideas for extending the sea level rise model:

Topics/icon connection	Student target explanations of system connection
15. Snow and ice cover → Species ranges	Reductions in sea ice decreases habitat which can alter species ranges.
16. Snow and ice cover → Species populations	As ice habitat decreases, populations dependent on this environment decline in numbers.
17. Greenhouse gases → Ocean acidification	Increasing carbon dioxide in the atmosphere due to human activities results in ocean acidification.



Exploring additional consequences of greenhouse gas emissions and global warming:

Extension activities/resources	UGC connections and icons	Disciplinary/ curricular standards (NGSS)
March of the Polar Bears: Global Change, Sea Ice, and Wildlife Migration, NASA https://mynasadata.larc.nasa.gov/sites/default/files/2018-12/March%20of%20the%20Polar%20Bears-%20Global%20Change%20Sea%20Ice%20and%20Wildlife%20Migration.pdf	Snow and ice cover, Species ranges, Species populations	HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new

CLEAN Link https://cleanet.org/resources/41870.html		ecosystem.
Extension Activities/Resources	**UGC Connections and Icons**	**Disciplinary/ curricular standards (NGSS)**
Our acidifying ocean, Stanford University **http://web.stanford.edu/group/inquiry2insight/cgi-bin/vu-r1a/vu.php?view=acidocean** **CLEAN Link** **https://cleanet.org/resources/43513.html**	Burning of fossil fuels, Greenhouse gases, Carbon cycle, Ocean acidification, Species populations, Life cycles and traits	HS-PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium. HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Students could also explore concepts that are of interest to them that are connected to the sea level rise mode. An example of an open-ended assignment could use the instructions below (also on Slide 69 of Deck 2).

The Earth is a system! Can we think about other measurable changes that are related to sea level rise, ice melting and global warming?

Add at least 1 new icon and connect it to any icon in your sea level rise model.

Provide evidence for why you think those components of the Earth system are connected. Evidence could be from a dataset or scientific news article providing information about this cause and effect relationship.