AMERICAN METEOROLOGICAL SOCIETY:

A COLDEX Center for Oldest Ice Exploration PARTNER

Project Ice

Land Ice, Sea Ice, Grounded Ice, and Impacts on Sea Level Rise

TEACHER'S GUIDE

Project Ice

This guide is one of a series produced by Project Ice, a National Science Foundation sponsored initiative of the American Meteorological Society (AMS). AMS is a subawardee of Oregon State University on its NSF Science and Technology Center institutional award (OPP-2019719), Center for Oldest Ice Exploration (COLDEX). The purpose of COLDEX is to “explore Antarctica for the oldest possible ice core records of our planet’s climate and environmental history, and to help make polar science more inclusive and diverse.” Project Ice is the annual K-12 teacher focused activity within COLDEX, and is offered via hybrid delivery that includes a one-week residency at Oregon State University. The goal of Project Ice is to create and train a diverse network of master teachers prepared to integrate paleoclimatology and polar science in their classrooms and provide peer training sessions. To support these teachers' educational experience, Project Ice develops and produces teacher's guides, slide sets, and other educational materials.

For further information, and the names of the trained master teachers in your state or region, please contact:

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This material draws from U.S. Ice Drilling Program School of Ice work supported by the National Science Foundation under Award #1836328. Some content is also based on AMS DataStreme course investigations, developed with support from the National Aeronautics and Space Administration (NASA) and National Oceanic and Atmospheric Administration (NOAA).

Figure i. Land Ice, sea ice, and open water over Greenland. [Photo by Linette Boisvert/NASA]

“The purpose of life is to live it, to taste experience to the utmost, to reach out eagerly and without fear for newer and richer experience.”

- Eleanor Roosevelt, First Lady of the United States

“We can't save the planet without uplifting the voices of its people, especially those most often unheard"

- Leah Thomas, intersectional environmentalist and author

Module: Land Ice, Sea Ice, Grounded Ice, and Impacts on Sea Level Rise
Instructor: Project Ice Instructor or Project Ice Graduate
Audience/Grade Level: K-12 Educators

STANDARDS:

Project Ice Objectives

Understanding Climate Change and Paleoclimate:

7. Examine the components and dynamics of Earth's climate system at local, regional, hemispheric, and global scales.

Studying Ice Dynamics and Glacial History:

2. Differentiate between the West Antarctic and East Antarctic Ice Sheets and their different responses to climate change.
3. Evaluate the importance of glacier dynamics and ice sheet stability in predicting rapid sea level rise, with a focus on how the instability of Thwaites Glacier highlights the urgency of these studies
4. Assess the impact of basal conditions, grounding line changes, and ocean interactions on glacial flow and ice sheet stability.
5. Investigate the role of ice shelves in stabilizing ice sheets and limiting ice flow into the ocean.

Climate Literacy Principles from: https://cleanet.org/clean/literacy/climate/index.htmlb

2. Climate is regulated by complex interactions among components of the Earth system. (b)
5. Our understanding of the climate system is improved through observations, theoretical studies, and modeling. (b,c)
6. Human activities are impacting the climate system. (c)
7. Climate change will have consequences for the Earth system and human lives. (a)

Next Generation Science Standards (NGSS)

Performance Expectations

2-ESS1-1. Use information from several sources to provide evidence that Earth events can occur quickly or slowly.

2-ESS2-3. Obtain information to identify where water is found on Earth and that it can be solid or liquid.

4-ESS2-2. Analyze and interpret data from maps to describe patterns of Earth’s features.

5-ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.

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.

HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

Science and Engineering Practices

2. Developing and Using Models
4. Analyzing and Interpreting Data
8. Obtaining, Evaluating, and Communicating Information

Disciplinary Core Ideas

ESS2.C: The Roles of Water in Earth’s Surface Processes

ESS2.D: Weather and climate

ESS3.C: Human Impacts on Earth Systems

Crosscutting Concepts

1. Patterns
2. Cause and Effect
4. Systems and System Models
7. Stability and Change

Engage | Changes in Earth's Cryosphere

There are examples worldwide of changes within Earth's **cryosphere**, the frozen part of the hydrosphere, one of the major components of Earth's climate system. The cryosphere includes sea ice (frozen ocean water, where most salt is excluded), glaciers, ice sheets, and permafrost. The hydrosphere and cryosphere are significantly impacted by global climate change.

Figure 1 shows changes in the Muir Glacier from 1941 to 2004. This glacier is part of Glacier Bay National Park in southeast Alaska. During the Little Ice Age maximum in 1750, ice filled all of Glacier Bay. By 1879, the ice front had retreated 45 miles, and presently it is 60 miles back. Muir Glacier used to be a "tidewater glacier" that calved icebergs into the Bay, but now its terminus, like that of many other glaciers in the area, is on land. (Note that tidewater glaciers experience a natural cycle of advance and retreat, but glaciers worldwide are impacted by climate change.)

Figure 1. In 1941 (left), Muir Glacier filled this valley in Glacier National Park and Preserve in Alaska. By 2004 (right), Muir Glacier had retreated 12 kilometers (7 miles) and thinned by more than 800 meters (2,600 feet). At present, the Muir Glacier ends on land whereas it used to be a tidewater glacier. [Photographs by William Osgood Field (1941) and Bruce F. Molnia (2004). From the Glacier Photograph Collection at the National Snow and Ice Data Center.]

Group Discussion:

1.) Explore how the Glacier Bay region of Southeast Alaska has changed over the last 30 years. What are the major changes you can see?
2.) Pick one of the following examples of before and after images that show the changeable nature of Earth's hydrosphere and cryosphere to focus on. What do you observe about the impact of climate change on your selected area?

Grand Plateau Glacier

Tibetan Plateau

Land Glacier, Antarctica

East Antarctic Ice Shelf

Explore | Global Climate Change and Sea Level Rise

One of the major impacts of global climate change is changes in sea level. Over Earth's history, paleoclimate data shows that sea level has varied dramatically. During the last glacial maximum about 20,000 years ago (within the Pleistocene Epoch), global sea level was approximately 120 meters lower than today. During the past 7,000–8,000 years of the Holocene (current geological epoch), sea level has remained fairly constant. However, global sea level has shown an upward trend since the second half of the 19th century due to human-caused warming of the climate system. According to NOAA, global sea level has increased by 21–24 cm (8–9 in.) since 1880. Since the end of the 20th century, the rate of sea level rise has more than doubled. According to NASA, in 2024, global sea level was 10.33 cm (4.07 in.) above the 1993 level, when satellites began measuring global sea level.

Sea level rise has significant societal consequences since 10% of the world's population lives in coastal areas 10 meters or less above sea level. In the United States, 30% of the population lives in coastal areas vulnerable to sea level rise, due to potential flooding, coastal erosion, and storm-related impacts.

Figure 2 shows satellite-based measurements of global sea level rise from 1993–2018, and independent estimates of the major contributors to this rise: added water mass and ocean thermal expansion (increased volume of the ocean due to warming of ocean water, resulting in higher sea level).

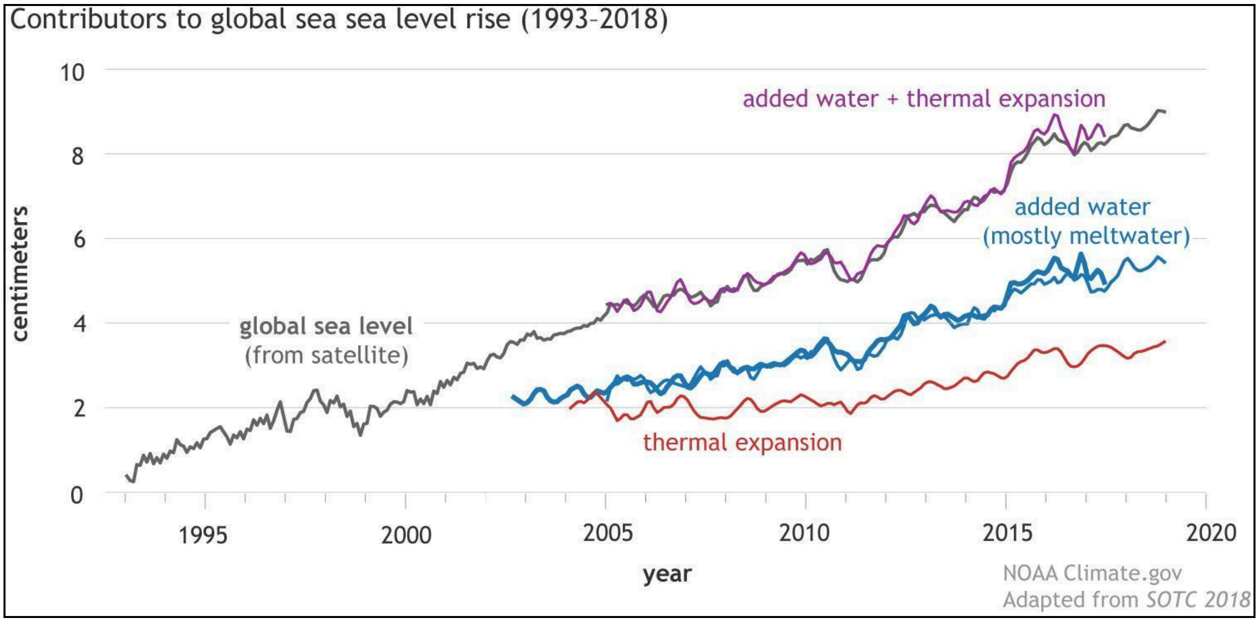

Figure 2. Observed sea level since the start of the satellite altimeter record in 1993 (black line), and independent estimates of the different contributions to sea level rise: thermal expansion (red) and added water, mostly due to glacier melt (blue). Added together (purple line), these separate estimates match the observed sea level very well. [Climate Change: Global Sea Level]

Group Review and Discussion:

1.) What has been the overall trend in global sea level since 1880? How has the rate of sea level rise changed in recent years?

2.) Ocean thermal expansion and added water are the major factors in global sea level change. Where does most of the additional water come from?

3.) Describe the contributions of these two major factors in 2005 vs. 2018.

Figure 3 shows that trends in sea level change are not uniform in the United States (nor are they worldwide). In particular, note the difference between the U.S. West Coast and the Gulf and East Coasts. Also, note how sea level is falling along the Alaskan coast.

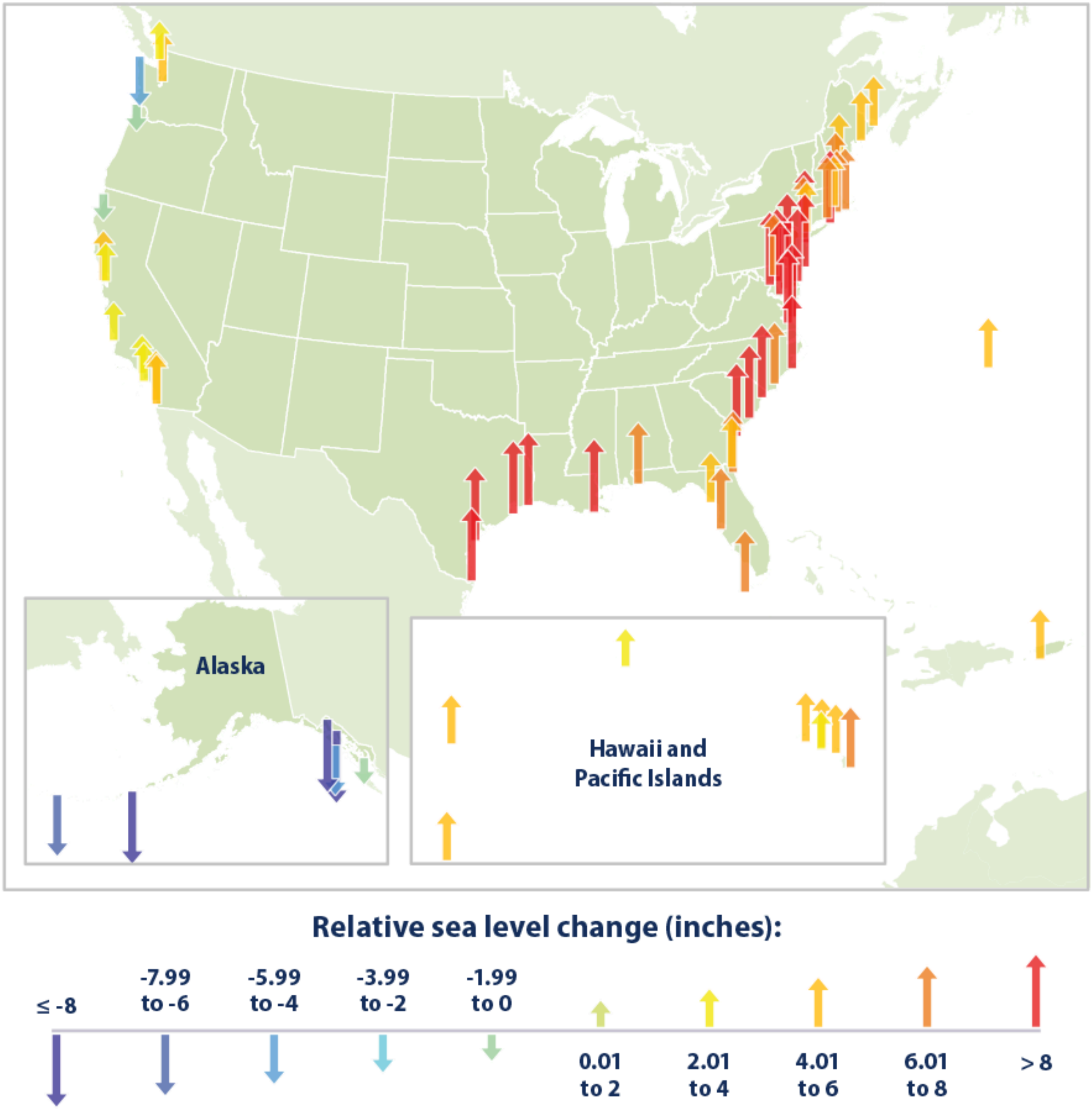

Figure 3. This map shows cumulative changes in relative sea level from 1960 to 2021 at tide gauge stations along U.S. coasts. Relative sea level reflects changes in sea level as well as land elevation. [Adapted from EPA, data originally from NOAA]

Go to Sea Level Trends to view these trends in more detail and examine observations in the United States coastal areas and elsewhere.

Interestingly, while glacial melt in Alaska contributes to global sea level rise, local sea levels are progressively decreasing. This results from a process called glacial isostatic adjustment and shifts in Earth's tectonic plates. Go to As Lands Rise, Alaska's Sea Level is Sinking to learn more.

Group Review and Discussion:

1.) In the majority of locations in the U.S. and worldwide, what is the trend in sea level?

2.) In the U.S. which regions show the largest positive and negative relative sea level changes?

3.) Why might a region experience decreases in local sea level?

4.) Worldwide, consider if the largest increases in local sea level generally occur at tropical, mid-latitude, or polar regions.

5.) Hypothesize how sea level might continue to change over the 21st century. Is it possible that polar regions that have experienced sea level decreases might experience future increases?

Explain | Types of Ice and Changes in Earth's Climate System

Types of Ice

Earth's cryosphere includes several different forms of ice, including glaciers, expansive ice sheets covering Greenland and Antarctica, sea ice, and **permafrost** or permanently frozen ground most commonly found in polar and/or mountainous regions.

In the polar regions, some of the surface ocean water freezes during the colder months of the year, forming **sea ice**. The ice contains relatively little salt as most of the impurities are excluded as ice crystals form. The salt trapped between crystals gradually migrates downward to the ocean below, leaving "freshened" sea ice. In the summer, most of the sea ice around Antarctica melts, but multiyear sea ice forms in the Arctic Ocean and persists for several years before flowing out through Fram Strait into the Greenland Sea and eventually melting. Seasonal sea ice is typically a meter thick, while multiyear sea ice can reach up to 10 m thick.

Glaciers are masses of ice that form on land in locations where annual snowfall exceeds annual snowmelt. The pressure of new snow falling on older snow transforms this underlying snow into ice. Glaciers are typically >50 m thick, enough that the ice begins to deform (flow) under its own weight. There are various types of glaciers worldwide; some examples were given in the initial section of this module.

Massive **ice sheets**, glacier land ice extending >50,000 square kilometers (>20,000 square miles) and reaching thousands of meters thick, are found on Greenland and Antarctica. The Greenland Ice Sheet and the two major ice sheets on Antarctica formed when annual layers of snow were eventually compressed into thick, dense masses of ice over thousands of years or more. **Ice shelves** are the portions of ice sheets extending over ocean water. Much of Antarctica, especially the western portion, is rimmed by major ice shelves (**Figure 4**). Ice shelves can be held in place by features in the bathymetry (e.g. underwater mountains).

Figure 4. Location of Antarctica ice shelves. [Agnieszka Gautier, NSIDC]

For the examination of global climate change and its impacts on sea levels, it's crucial to grasp the dynamics of ice sheets, encompassing glacier flow and the floating portion (ice shelf) extending over water. Additionally, understanding how the ice sheet is anchored (or grounded) to the bedrock is essential. Equally important is comprehending the formation of sea ice and its significance in polar regions.

Figure 5(a) is a diagram of Thwaites Glacier, which is part of th*e West Antarctic Ice Sheet (WAIS)* on the Antarctic Peninsula; **(b)** is a photograph of the "tongue" of Thwaites Glacier on the left side with sea ice seen on the right side of the image. As detailed in the Project Ice module "Understanding the Polar Regions," the WAIS is a marine ice sheet, which sits atop a series of islands and the floor of the Southern Ocean, with parts of the ice sheet more than 1.7 km (1 mi.) below mean sea level. This geography makes the WAIS much less stable than the thicker *East Antarctic Ice Sheet (EAIS)*, situated well above sea level. Thwaites is a large glacier, comparable to the size of Florida, and particularly unstable due to the bedrock in that area being primarily below sea level, and its underside sensitive to changes in ocean temperature and salinity.

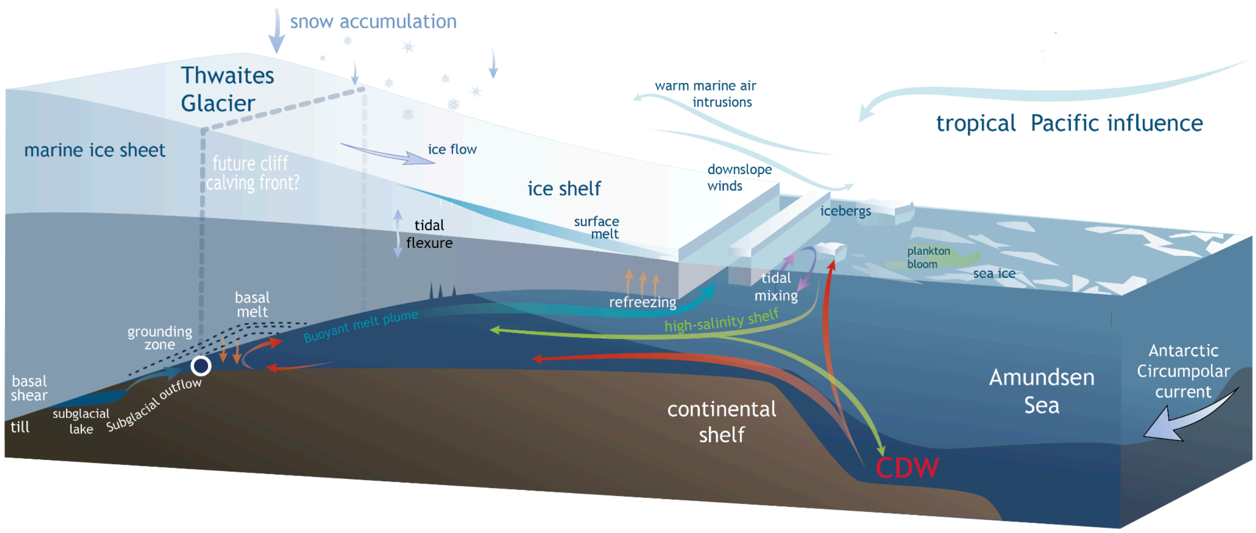

Figure 5a. Diagram of Thwaites Glacier in the West Antarctic Ice Sheet (WAIS), and the key processes impacting its stability. [Adapted from Scambos et al. 2017]

Figure 5b. Photo of the "tongue" of Thwaites Glacier, with sea ice also visible on the right side of the image. [Photo by NASA/James Yungel]

Examine the following features of Figure 5a: marine ice sheet, arrow showing ice flow within Thwaites Glacier, ice shelf, formation of patches of sea ice, and the grounding zone. The **grounding line** is where the ice first begins to float; it extends upward from the contact of ocean water with bedrock to the surface of the ice sheet. **Grounded ice** is ice that is in contact with the underlying bedrock and is not floating. The weight of grounded ice is supported by land. The grounding line forms the boundary between the floating portion of the ice sheet (the ice shelf) and the glacier, which is land based.

Glacier ice flows slowly from sources at higher elevations to lower elevations, where the ice melts and flows into the ocean. The NOAA GFDL site Ice Sheet Dynamics describes the dynamic nature of ice sheet flow.

Ice sheets flow due to the weight of their own mass. **Ice streams** are areas of accelerated flow within the ice sheet, and play an important role in moving ice from the interior of the ice sheet to its margins. The rate of ice flow depends on the balance between gravity, basal resistance opposing the ice sheet motion, and internal ice deformation. **Basal resistance** is the friction or resistance that the base of the ice sheet encounters as it moves over bedrock or a substrate; it is influenced by the roughness and composition of the bedrock, the presence of meltwater, and the pressure exerted by the overlying ice. Basal resistance dictates whether ice sheet flow is dominated by *basal* *sliding*, observed in ice streams, or *vertical shear*, prevalent when parts of the ice sheet are frozen to the bed.

The NOAA GFDL site also details the importance of the grounding line, which determines the horizontal reach of the marine ice sheet. Ice discharged across the grounding line to the ice shelf plays a significant role in the ice sheet's contribution to global sea level rise. A prevailing hypothesis on marine ice-sheet instability suggests a sole dependence on local bedrock slopes; a recent theory (Haseloff and Sergienko, 2018) suggests that the integral properties of the ice shelves also play an important role.

The site AntarcticGlaciers.org has numerous visuals of the grounding line and how it can be mapped, along with current and projected climate change impacts. **Figure 6** shows the bedrock elevation of Antarctica and inward retreat of grounding lines over time. The present day grounding line is depicted by the black dashed line; the red line is a simulation of the grounding line at the last interglacial, and the solid black line is a simulation of the grounding line at the last glacial maximum.

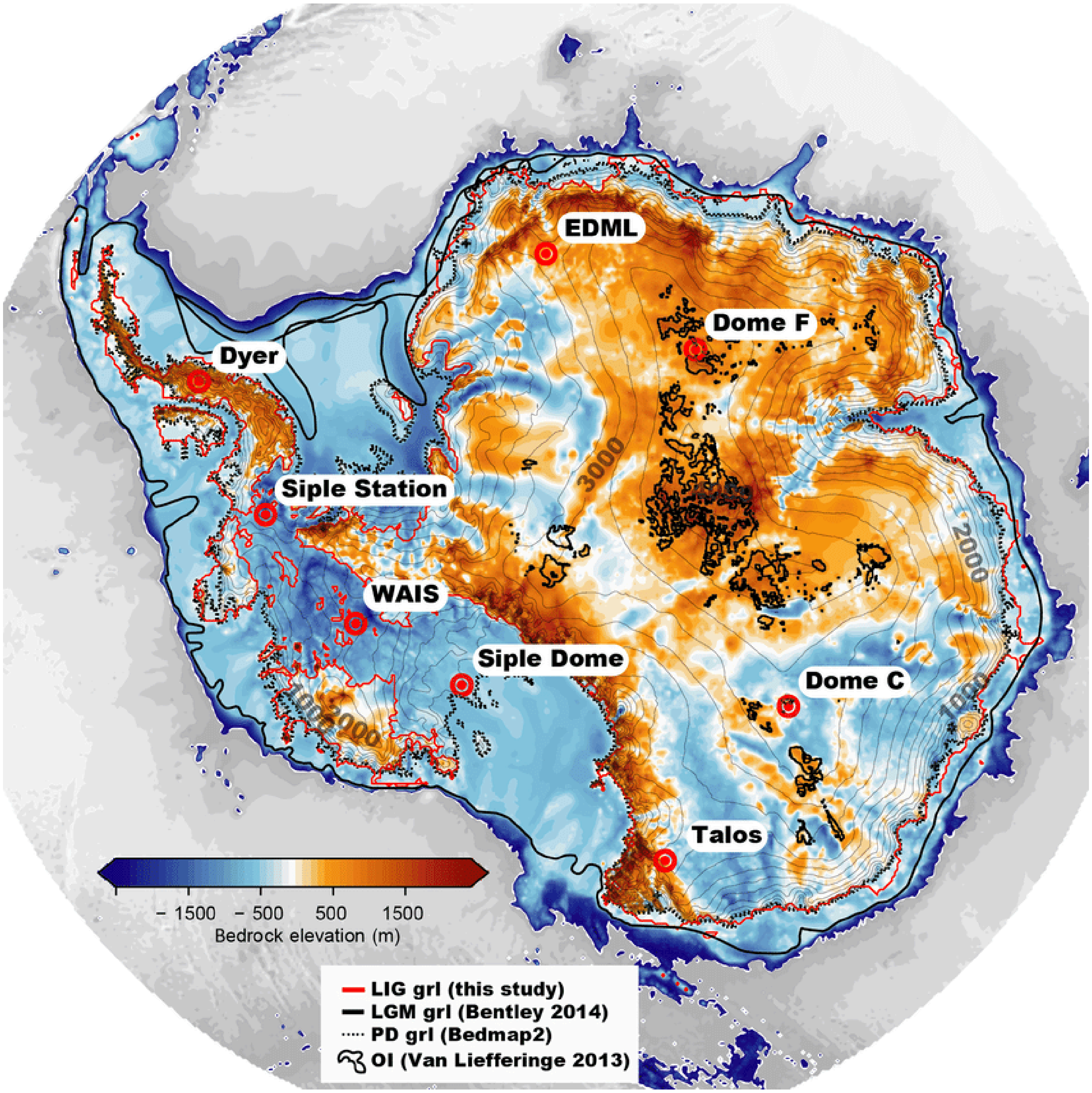

Figure 6. Antarctic bedrock topography with contours (gray lines). The present-day (PD) grounding line (grl) from BEDMAP2 (Fretwell et al., 2013) depicted by the dashed black line. The Last Glacial Maximum (LGM) grounding line reconstruction from Bentley et al. (2014) (thick black lines) is compared to simulated grounding line retreat in one of the ensemble members for the Last Interglacial (LIG, red line). Regions previously identified as potentially viable sites for Oldest Ice (Van Liefferinge and Pattyn, 2013) are outlined by thick black lines. [Sutter, J., Fischer, H., Grosfeld, K., Karlsson, N. B., Kleiner, T., Van Liefferinge, B., and Eisen, O., 2019]

Land Ice, Grounded Ice, and Floating (or Sea) Ice
To explore the impact of melting ice on global sea level rise, it is helpful to separate ice into three categories

Land-based ice: glaciers, snow on mountains, ice sheets
Floating Ice: sea ice, ice shelves (the extensions of land-based ice sheets), icebergs
Grounded ice: ice resting on Earth's bedrock behind the grounding line

The melting of land-based ice (e.g. ice sheets, mountain glaciers) contributes to sea level rise, as seen in Figure 2 (added meltwater). Meltwater from land-based ice usually does not enter the ocean directly. Instead, land-based ice flows toward the coast and pushes out to become an ice shelf that then breaks up. Warmer water and air temperatures, along with other circulation factors, contribute to the breakup of ice shelves. While this floating ice has minimal impact on sea level, ice shelf breakup allows glacier flow on the land-based ice sheet to accelerate, and this input of ice/water leads to sea-level rise.

Floating ice (sea ice, ice shelves, and icebergs) is already displacing the ocean water surrounding it. Upon melting, the input of this fresh water has no impact on sea level. There are various ways of visualizing this, but a simple experiment is to have a clear container of water, place ice cubes in the water, mark the height of the water surface, and then let the ice completely melt and mark the final height of the water surface. While floating ice that melts has little direct effect on sea level, melting sea ice has a significant effect on Earth's total albedo and the resulting feedback loop described in the Project Ice Module "Understanding the Polar Regions."

Grounded ice is the portion of the ice sheet behind the grounding line. The position of the grounding line is strongly influenced by characteristics of the ocean underlying the ice shelf. If ocean temperatures warm, more ice at the grounding line melts, allowing the grounding line to retreat inland, raising sea level.

Observed Changes in the Antarctic
The Intergovernmental Panel on Climate Climate (IPCC) Polar Regions Fact Sheet, based on the Sixth Assessment Report, succinctly describes aspects of climate change in the Antarctic. Major conclusions are summarized below:

- "Both major ice sheets – Greenland and Antarctica – have been losing mass since at least 1990, with the highest loss rate during 2010–2019 (high confidence), and they are projected to continue to lose mass.

- Observations show a widespread, strong warming trend starting in the 1950s in the Antarctic Peninsula. Significant warming trends are observed in other West Antarctic regions and at some stations in East Antarctica (medium confidence).
- The Antarctic Peninsula, West Antarctica and some East Antarctic regions are projected to continue to warm in the 21st century at a rate greater than the global average.
- Antarctic snowfall and net snow accumulation have increased over the 20th century (medium confidence).
- Mass losses from West Antarctic outlet glaciers, mainly induced by ice-shelf basal melt, outpace mass gain from increased snow accumulation on the continent.
- At sustained warming levels between 2°C and 3°C, the West Antarctic Ice Sheet will be lost almost completely and irreversibly over multiple millennia; both the probability of complete loss and the rate of mass loss increase with higher surface temperatures.
- For Antarctic sea ice, there is no significant trend in satellite-observed sea ice area from 1979 to 2020 in both winter and summer, due to regionally opposing trends and large internal variability."

On the last point regarding Antarctic sea ice, there is now evidence of a potential downward trend as 2022, 2023, and 2024 sea ice minimums were the lowest in the satellite-observed record.

Group Review and Discussion:

1.) Explain how an ice sheet flows.

2.) How does the infusion of 'warmer' than normal ocean water under the ice shelves impact the position of the grounding line?

3.) Explain how the melting of land ice, floating, and grounded ice impacts sea level.

4.) Of the WAIS, EAIS, and Greenland Ice Sheet, which is the most stable and why?

Elaborate | Climate Change Projections, Ice in the Antarctic, and Sea Level Change

The Polar Regions are particularly sensitive to warming of Earth's climate system. Temperature changes tend to be amplified in these regions, and the cryosphere is sensitive to these changes. Scientists are concerned about how warmer ocean water and air temperatures are affecting Antarctic glaciers, particularly in the WAIS where much of the ice sheet is grounded by bedrock below sea level. Thwaites Glacier, which is 192,000 km^2 (74,100 $mi.^2$), slightly smaller than Great Britain and similar in size to Florida, is of particular concern. The Cooperative Institute for Research in Environmental Sciences (CIRES) notes that mass loss at Thwaites accounts for 4% of annual global sea level rise. Glacial breakup could lead to 2 ft. of sea level rise over the course of centuries, and much more if its breakup destabilizes other areas of the WAIS. Thwaites is one of many glaciers in Antarctica being impacted by climate change.

Watch the video [What is happening at Thwaites Glacier? International Thwaites Glacier Collaboration] to learn more about what is happening at Thwaites Glacier. Then, review the page [The threat from Thwaites: The retreat of Antarctica's riskiest glacier.]

1. Thwaites Glacier in the West Antarctic Ice Sheet is particularly sensitive to climate change because the grounding line is:
   a. well below sea level
   b. near sea level
   c. well above sea level

2. The presence of an intact ice shelf _______ glacier outflow.
   a. helps slow down
   b. does not have much impact on
   c. helps accelerates

3. On Thwaites Glacier, what is the main factor in ice shelf breakup?
   a. Warmer air temperatures creating meltwater
   b. Increased precipitation over the West Antarctic Ice Sheet
   c. Warmer and salty ocean water melting the ice sheet from below
   d. Stronger winds over the West Antarctic Ice Sheet

4. Retreat of the grounding line inland _______ the volume of the ice sheet.
   a. increases
   b. has little effect on
   c. decreases

5. Retreat of the grounding line will likely _______.
   a. stabilize the ice front and slow ice flow
   b. destabilize the ice front and lead to faster ice flow
   c. not affect the speed of ice flow

6. If the WAIS were to break up over the course of centuries, it could lead to _______ of global sea level rise.

a. 5 cm (2 in.)
b. 25 cm (10 in.)
c. 60 cm (2 ft.)
d. 3 m (10 ft.)

While we are focusing on the WAIS in this module, it is important to remember that there are other areas of glacier ice worldwide, such as the Greenland Ice Sheet and other types of glaciers at more temperate climates. While the ice volume is not as great as in the Antarctic ice sheets, these areas are strongly affected by warming temperatures and are important contributors to sea-level rise. In fact, the contribution of Greenland's ice sheet melting to global sea level rise is currently slightly greater than the Antarctic ice sheets.

Climate models are an essential tool for understanding and predicting natural and human-induced climate change and implications for sea-level. Projected changes are commonly described in IPCC reports, such as the [IPCC Special Report on the Ocean and Cryosphere in a Changing Climate](). These reports use different scenarios to predict the possible changes in Earth's climate based on greenhouse gas emissions and other factors. This report uses Representative Concentration Pathway (RCP) emission scenarios, in which higher-numbered scenarios represent higher emissions. In **Figure 7**, RCP2.6 represents a lower level of future greenhouse gas emissions with the enactment of significant climate policies, and RCP8.5 represents a high level of greenhouse gas emissions, akin to a "business as usual" scenario without additional climate policies.

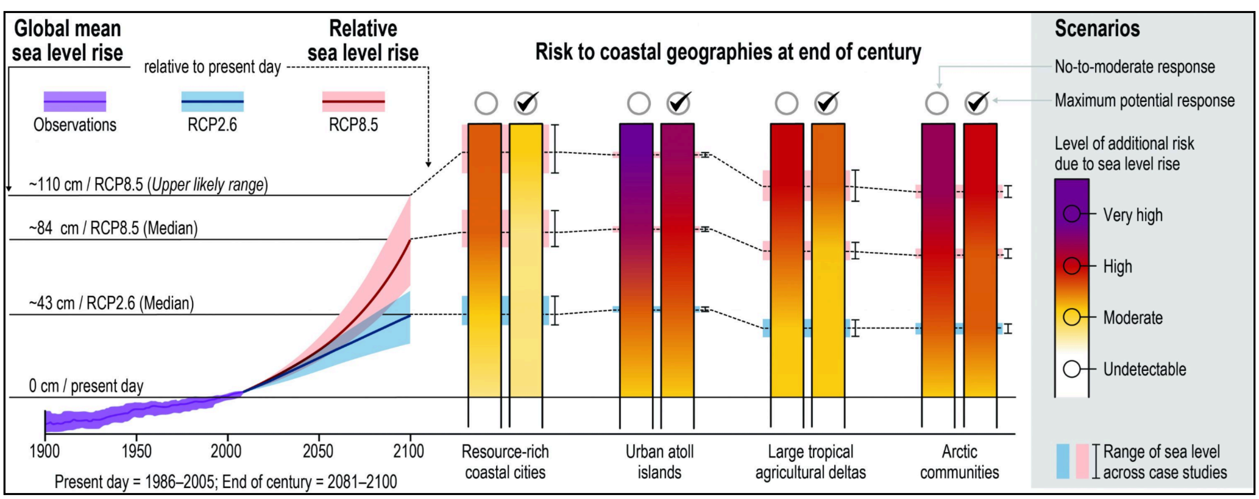

Figure 7. Global and regional sea level rise (SLR) risk for low-lying coastal areas by the end of the 21st century. [Figure 4.3 from *IPCC Special Report on the*

Ocean and Cryosphere in a Changing Climate]

7. According to the left panel in Figure 7, under the median value of RCP2.6, how much will the global sea level rise by 2100 compared to the present-day level?
   a. 15 cm (5.9 in.)
   b. 43 cm (16.9 in.)
   c. 84 cm (33.1 in.)
   d. 110 cm (43.3 in.)

8. According to Figure 7, what is the impact on resource-rich coastal cities under RCP2.6 (Median) with no-to-moderate response?
   a. undetectable
   b. moderate
   c. high
   d. very high

9. According to Figure 7, under the median value of RCP8.5, how much will the global sea level rise by 2100 compared to the present-day level?
   a. 15 cm (5.9 in.)
   b. 43 cm (16.9 in.)
   c. 84 cm (33.1 in.)
   d. 110 cm (43.3 in.)

10. What is the impact on urban atoll islands under RCP8.5 (Median) with a maximum potential response?
   a. undetectable
   b. moderate
   c. high
   d. very high

To visualize the impact of sea-level rise on coastal cities under 2°C and 4°C warming, go to Climate Central - Sea Level Rise and the Fate of Coastal Cities. Note that 2°C of warming would be approximately associated with the upper limit of the RCP2.6 scenario; 5°C of warming would be approximately associated with the median RCP8.5 scenario, so 4°C would be at an emissions scenario between RCP2.6 and RCP8.5.

11. It is clear that without mediating factors (e.g. significant engineering design), major coastal cities could experience ________ flooding due to sea level rise by 2100.
   a. minor levels of
   b. major levels of

Evaluate | Summarizing Types of Ice and Sea Level Rise

To review what has been presented and investigated during this module:

12. What is(are) the major factor(s) in global sea level rise?
    a. Ice sheet and glacier melt
    b. Thermal expansion
    c. Increased precipitation
    d. Both a and b are correct
    e. Both b and c are correct

13. Under the climate modeling RCP2.6 scenario, global sea level would increase a little over 1 ft. by _______.
    a. 2030
    b. 2050
    c. 2100
    d. 2200

14. Regional sea level changes _______ global changes.
    a. are consistently similar in direction and magnitude to
    b. can differ in direction and magnitude by geographical region compared to

15. Which Antarctic ice sheet poses the most immediate concern to sea level rise?
    a. East Antarctic Ice Sheet
    b. West Antarctic Ice Sheet

16. With warming ocean temperatures, the grounding line:
    a. retreats
    b. remains in the same location
    c. advances

17. Which of the following types of ice, if melted, raises sea level?
    a. grounded
    b. land
    c. sea
    d. Both a and b are correct.
    e. Both b and c are correct.

18. The water content of Thwaites Glacier translates into approximately _______ ft. of global sea level rise.

a. 0.5
b. 2
c. 10
d. 50

19. The breakup of an ice shelf _______ glacier flow.
a. accelerates
b. decelerates
c. has no effect on

Workshop Extensions
"Land Ice/Sea Ice/Grounded Ice"