1.4 Climate Change Anomalies and Suffering Economies

AGE RANGE
9th—12th grade

TIME REQUIRED
90 minutes

ACTIVITY OVERVIEW
Engage: Equal vs equitable
Explore: Reading
Explain: Discussion
Elaborate: Modeling
Evaluate: Discussion and graphs

MATERIALS
Computers

BASED ON:
Lesson adapted from KBS K-12 Partnership Predicting Earth's Future: Building your own climate

LESSON TOPIC: Economics and modeling

ACTIVITY SUMMARY: Students use carbon emission data to create a climate change model.

OBJECTIVES:

Students will be able to:

- Explain what a model is and the basic components that go into constructing a model.
- Explain how climate and sea-level rise models work, including their limitations.
- Understand the connection of sea-level rise and economics.

LESSON BACKGROUND:

ECONOMICS

Rising sea levels impact communities by increasing rates of flooding, exacerbating existing hazards like erosion, and damage community infrastructure. This causes direct impacts on coastal economies through costly damage to individuals, businesses, municipalities, closed businesses, and displaced consumers. It also causes indirect impacts by reducing industry production, increasing real estate pressure, and causing long-term shifts in coastal development patterns.

MODELING

We know that sea level is rising based on measurement data collected from tide gauges and satellites. Scientists use models to estimate how much and how fast sea level will continue rising. There are two different approaches to models: process-based and semi-empirical. Process-based models consider the different physical processes that cause sea levels to rise. Semi-empirical models extrapolate the information contained in measurements of past sea level changes.

Process-based models used for sea-level rise projections quantitatively describe the contributors of sea-level rise: thermal expansion of water and addition of water volume from melting land-ice. Three-dimensional ocean circulation models can be used to model thermal expansion. Determining the rate that heat warms the ocean surface and how deep the water is warmed below the surface are important for this model. One limitation is that as climate change alters ocean circulation, the intensity of ocean mixing changes and leads to uncertainty in the model. Another limitation is the difficulty in measuring the addition of water volume from melting land-ice because there are so many glaciers. The World Glacier Inventory contains ~123,000 glaciers (Radic and Hock 2010). Scientists cannot model the dynamics of each glacier individually. Glaciers are measured using semi-empirical scaling laws to estimate total volume from satellite measured surface area. Due to the uncertainty of glacier volume, this glacier melt could contribute as little as 5 cm (Raper and Braithwaite 2006), around 10 cm (IPCC 2007), or more than 37 cm (for moderate levels of climate change; (Bahr et al. 2009) to sea-level rise by the year 2100. The science to watch is the study of melting land-ice. Every year scientists are improving measurements of melting glaciers and in turn improving the projected range of sea-level rise models.

Semi-empirical models try to extrapolate the link between observed sea-level rise and observed global temperature changes in the past in order to predict the future. The starting point is the simple physical idea that sea level rises faster as it gets warmer. An advantage of semi-empirical projections is that they reproduce the observed past sea-level rise. A limitation is that we cannot be sure that the pattern from the past will continue to hold in the future.

Models are updated with new understanding as our research improves. As the understanding of natural processes, especially the increased understanding of glacier melt, improves, the results are used in process-based models to provide more robust projections of future sea-level rise.

Both types of models put out a range of potential sea-level rise scenarios that provides a framework of possible outcomes based on what we know. This includes accounting for our understanding of models' limitations, the range of potential future carbon emissions, and natural variability. The range of sea-level rise projections allows communities to plan for a changing coastline.

Background information adapted from: Rahmstorf, S. (2012) Modeling sea level rise. Nature Education Knowledge 3(10):4

VOCABULARY:

Economics	Economics is a social science concerned with the production, distribution, and consumption of goods and services.
Model	Systematic depiction of current and/or future conditions for different processes. Model climate tool types include theoretical, numerical, and conceptual and can range from simple to complex.
Semi-Empirical Models	A model involving assumptions, approximations, or generalizations designed to simplify calculation or to yield a result in accord with observations.
Process-Based Model	A mathematical representation of one or several processes characterizing the functioning of well-delimited biological systems of fundamental or economical interest.
Visualization	Climate tool type that creates simulations or graphics of current and/or potential future conditions.
Vulnerability	Potential for assets to be adversely affected by hazards. Encompasses exposure, sensitivity, potential impacts, and adaptive capacity.

ENGAGE

Show students the image “Societal Options for Resource Allocation in a Changing Climate” without the figure legend (on the next page). Ask the students what they see in the pictures and what the boxes represent for sea-level rise preparedness.

Societal Options for Resource Allocation in a Changing Climate

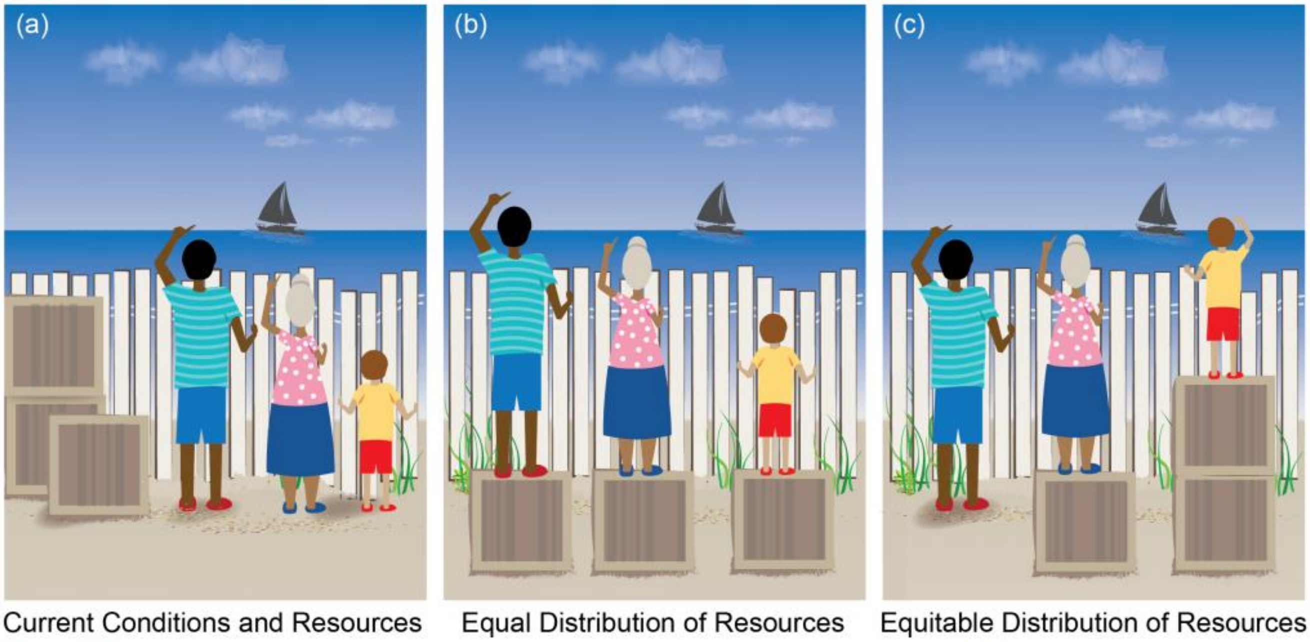

Figure 8.5: Society has limited resources to help individuals and communities adapt to climate change. Panel (a) illustrates that there are finite resources available and that individuals and communities are starting from different levels of readiness to adapt. Panel (b) illustrates the option for society to choose an equal allocation of resources where everyone gets the same amount of help, or as illustrated in panel (c), society can choose to distribute resources equitably to give people what they need to reach the same level of adaptation. Source: adapted with permission from Craig Froehle.

EXPLORE

Have students read "Economic Loss Due to Frequent Flooding."
Use Think-Pair-Share with the class to answer questions about the text:
T : (Think) Students "think" about what they know or have learned about the topic.
P : (Pair) Each student should be paired with another student or a small group.
S : (Share) Students share their thinking with their partner. Can be expanded into a whole-class discussion.

Student questions:
How does flooding impact business operation?
Why are businesses important in your community?
What might a business do if high tide flooding occurs more frequently?
What might a homeowner do if high tide flooding impacts their route to school? Work? Recreation?
Why might a family not leave their community even with frequent flooding?

EXPLAIN

We see that sea level is rising and that it will have large impacts, as well as making existing flooding worse. We can investigate the past for measurements recorded by human instruments as well as records stored in ice cores. To prepare our communities for the future of sea-level rise it is important to be able to predict how fast and how much the sea level will rise. Climate change is a result of many factors contributing to increased concentrations of greenhouse gases like carbon dioxide. Sea-level rise results from multiple factors increasing the level of the ocean, like thermal expansion of water and melting land-ice. To predict the future of sea-level rise, scientists take data about the factors contributing to sea-level rise and create models.

Some of these factors are variable while others don't really change even over the course of decades. Scientists must decide which factors to include in their models and how much weight to give to each of them in order to construct a model that can make accurate and precise predictions.

ELABORATE

Students use provided data and spreadsheet/graphing software (Google Sheets or Excel) to model climate impacts.

Tell students: Today, you are a climate scientist working for the Intergovernmental Panel on Climate Change and your job is to prepare a brief report for the United Nations showing the long-term effect of certain carbon emissions policies. You will start by developing a model to predict the average global temperature in the year 2050 and then you will use your model to estimate how much things will change if certain policies are enacted. At the end, you will turn in two things: this worksheet with questions and tables filled in and a copy of all the graphs you make using Google Sheets.

Students will complete the worksheet and create graphs using the data.

EVALUATE

Ask students or review their worksheet:

In what ways do you think your model is accurate?

What other variables do you think would help your model? What other things could influence global temperatures that could be included?

Relate the modeling activity back to economics:

How are economies impacted by climate change and sea-level rise?

How can communities or nations use modeling information to have more resilient economies in the future?

> **EXTENSION**: students can propose two policy changes that the United States could make that would slow the warming trend worldwide.

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Answer the following questions after reading "Impacts from Increased Flooding."

1. How does flooding impact business operation?

2. Why are businesses important in your community?

3. What might a business do if high tide flooding occurs more frequently?

4. What might a homeowner do if high tide flooding impacts their route to school? Work? Recreation?

5. Why might a family not leave their community even with frequent flooding?

You are tasked with developing a model to predict the average global temperature in the year 2050. Complete this worksheet and create graphs using a computer.

As you build your climate model, you will have to make several decisions about what data to include in it. To do this, you will make a series of graphs that show the relationship between different climate variables and global temperature and decide which ones make sense to include in your model. Below are descriptions of the data you are using, some going back to 1750 (some data are more limited because we only started collecting the data more recently):

You can access the data here: https://tinyurl.com/y6ozfo3b
(full link: https://docs.google.com/spreadsheets/d/1b4O2APcy-V9gzJg9ZJ8hctDvZfvqg-U9T-Ojnevv4pI/edit?usp=sharing)

Select all the data and copy it into a new spreadsheet document.

Global Temp: The average land surface temperature of the Earth based on interpolations from weather stations all over the Earth (data source: Berkley Earth)

Catastrophic Volcanos: Number of catastrophic volcanic eruptions around the world during that year (a "catastrophic" volcanic eruption is a volcanic eruption rated at a 3 or higher on the Volcanic Eruption Index) (data source: National Centers for Environmental Information)

Aerosol Optical Depth: A general measure of the concentration of aerosols (small particles found in dust, smoke, and ash) in the atmosphere that can shade out sunlight (source: National Centers for Environmental Information)

Sunspot Number: The average number of sunspots on the sun in a given year (data source: National Centers for Environmental Information)

CO_2 Concentration: The average global atmospheric CO_2 concentration during in a given year (data source: Institute for Atmospheric and Climate Science)

Cattle in USA: The total number of cows in the USA during in a given year (data source: National Agricultural Statistics Service)

Step 1: Variability Over Time

To model what will happen in the future you will need to determine if the variables follow a pattern. For each variable, use Google Sheets make a graph showing how it changes over time (you will make six graphs for this part). Be sure to label your axes and give each graph a title. A line graph would be a good way to represent these data.

After making your six graphs, fill in the table below, briefly describing the trend in the data (is it increasing, decreasing, or staying the same over time), variability (is the trend fairly constant over time or does it vary widely from year-to-year), and general notes on the pattern that you see.

Variable	General Trend	Variability	Notes
Global Temperature			
Volcanic Eruptions			
Sunspot Number			
CO_2 Concentration			
Cattle in USA			
Aerosol Optical Depth			

Step 2: Relationship with Temperature

After determining if the variables follow a pattern, you need to examine how they affect global temperature. Now use Google Sheets to make series of graphs that show the relationship between each variable (x-axis) and the global temperature (y-axis), then fill in the table below. Be sure to label your axes and give each graph a title.

Note: Since you aren't looking at change over time, it's not appropriate to use a line graph here. You will have to visualize your data with a scatterplot.

Fill in the table below to indicate the relationship between that variable and global temperature (are they positively related, negatively related, or unrelated) and the strength of any relationship (is it a strong relationship or just a weak one with a lot of variation).

Variable	Direction of Relationship	Strength of Relationship	Notes
CO_2 Concentration			
Sunspot Number			
Cattle in USA			
Aerosol Optical Depth			
Volcanic Eruptions			

Step 3: Building Your Model

Now we need to decide which variables to include in your model. Based on the relationship between global temperature and each variable, decide whether or not you think it would be important to include that variable in your model (Circle Yes or No) and briefly justify your decision.

CO_2 Concentration	YES	NO
Sunspot Number	YES	NO
Cattle in USA	YES	NO
Aerosol Optical Depth	YES	NO
Volcanic Eruptions	YES	NO

You know two things about each variable: how it changes over time and how it is related to average global air temperature. Now it's time to put your model together. For each of the variables you chose to include in your model, look back at your graphs from Step 1 and extrapolate the trend forward to the year 2050 to see what that value is. (Remember, you only need to include the variables you decided to include in your model from above)

Variable: _________________________________ Value in 2050: ___________

Variable: _________________________________ Value in 2050: ___________

Variable: _________________________________ Value in 2050: ___________

Variable: _________________________________ Value in 2050: ___________

Variable: _________________________________ Value in 2050: ___________

Now look at your graphs from Step 2 and make a prediction for what the temperature is likely to be in 2050 based on 2050 values you determined above.

Variable: ______________________________ Predicted Temp in 2050: __________

Variable: ______________________________ Predicted Temp in 2050: __________

Variable: ______________________________ Predicted Temp in 2050: __________

Variable: ______________________________ Predicted Temp in 2050: __________

Variable: ______________________________ Predicted Temp in 2050: __________

Lastly, calculate an average of the predicted temperatures from each of the variables above to determine your final prediction.

Your prediction for average global air temperature in 2050: __________________

In what ways do you think your model is accurate?

What other variables do you think would help your model? What other things could influence global temperatures that could be included?

ECONOMIC LOSS DUE TO FREQUENT FLOODING

Coastal flooding has increased across much of the United States. Sea-level rise is causing more frequent flooding outside of extreme weather conditions. Flood damage causes negative impacts to property and buildings, but it also extends to impacting business and community life. Researchers Hino, Belanger, Field, Davies, and Mach (2019) studied the impacts on business caused by high tide flood events in Annapolis, Maryland. In 2017, Annapolis had high tide flooding occur on 63 days, particularly affecting the historic downtown area. For us living along the Gulf of Mexico from Florida to Mississippi, by 2050 we will experience high tide flooding on average between 25 to 80 days each year. Understanding effects in similarly impacted communities will help us plan for impacts in our communities. The research in Annapolis, Maryland demonstrates that high tide flooding does affect their local economic activity, and the number of people visiting the historic downtown was reduced by 1.7% during flood events. Future sea-level rise will further increase the number of high tide flooding days. With just 3 inches of additional sea-level rise, the increased frequency of high tide floods would reduce visits by 3.6%, resulting in negative impacts from reduced tourism and economic exchanges. When businesses are closed, it reduces revenues that support the community through sales tax, lodging tax, and other sources. Without this revenue, the budgets of cities, towns, and counties will be reduced, minimizing the amount of services (e.g., police, fire fighters, schools, road repairs, etc.) the municipalities can provide to their residents. Understanding how frequent flooding leads to economic loss will help guide local adaptations to prepare for climate change impacts.

SOCIETAL IMPACTS DUE TO SEA-LEVEL RISE

Climate change and sea-level rise pose risks to coastal communities around the world. Researchers Martinich and colleagues (2013) used an analytic tool to identify geographic areas in the contiguous United States that may be more likely to experience disproportionate impacts of sea-level rise and to determine if and where socially vulnerable populations would bear disproportionate costs of adaptation. They identified socially vulnerable coastal communities in four regions of the United States: North Atlantic (Maine through Virginia), South Atlantic (North Carolina through Monroe County, Florida), Gulf (Collier County, Florida through Texas), and Pacific (California through Washington). To evaluate if the communities threatened with sea-level rise would have the economic ability to adapt to the changes, they combined the vulnerable community output with a sea-level rise model. Their results show that under the mid sea-level rise scenario with around 67cm of rise by 2100, approximately 1,630,000 people are potentially affected by sea-level rise. Of the people affected, about 332,000 (~20%) are among the most socially vulnerable. Areas of higher social vulnerability are much more likely to be abandoned than protected in response to sea-level rise. In the Gulf region over 99% of the most socially vulnerable people are living in areas that are unlikely to be protected from sea-level rise inundation. In comparison, of the least socially vulnerable group in the Gulf region, only 8% of people live in areas unlikely to be protected. These results demonstrate the need to consider economic barriers of communities facing sea-level rise impacts.

First reading adapted from: Hino, M., Belanger, S., Field, C., et al. Science Advances (2019) 8: EAAU2736 https://doi.org/10.1126/sciadv.aau2736

Second reading adapted from: Martinich, J., Neumann, J., Ludwig, L. et al Mitigation and Adaptation Strategies for Global Change (2013) 18: 169. https://doi.org/10.1007/s11027-011-9356-0

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DO NOW:

Draw a downtown “Main Street.” Then draw how high tide flooding might impact the area.

EXIT TICKET:

How does sea-level rise impact the economy?