MIAMI WATERKEEPER®

CLIMATE CHANGE LESSON PLAN

SEA LEVEL RISE: A HIDDEN POLLUTER

INSTRUCTOR BACKGROUND:

For this lesson plan we will be learning about one of the most talked about environmental issues in South Florida: **sea level rise**. We will be diving into this issue deeper than the general approach of melting ice caps due to increased temperatures due to **climate change**. Sea level rise effects vary from city to city; this lesson plan is aimed at describing sea level rise here in South Florida and what kind of water pollution issues stem from its occurrence. Students should have a basic understanding of **geography** and the **water cycle**, also known as a **hydrologic cycle**. They should be prepared to learn about how climate change causes sea level rise (by melting ice caps as well as thermal expansion) and the scientific properties of water. Students will learn about the extensive impacts sea level rise brings with it, including **flooding**, **saltwater intrusion**, **dormant pollution release**, **king tides**, and **compromised septic systems**. The objective of this lesson plan is to showcase how sea level rise occurs, its current and future impacts on South Florida, and how to take steps to be more resilient.

Recommended for grades 9-12, but can be adapted anywhere from grades 6-12.

After using this lesson plan, we would love for you to write a short review using the following link to access a survey:
Click here to review this lesson plan!

Your responses will help make these resources and future ones better!

DOWNLOADABLE LESSON PLANS

MIAMI WATERKEEPER

Miami Waterkeeper's mission is to ensure swimmable, drinkable, fishable water for all.

Founded in 2010, Miami Waterkeeper defends everyone's right to use and enjoy clean water. Our scope of work is diverse, with focus areas including clean water, ecosystem protection, and sea level rise readiness.

TIMELINE

PRESENTATION:	20-35 MINUTES
ACTIVITY (*some will be homework to be started in class*):	20-30 MINUTES
DISCUSSION:	5-10 MINUTES
NEXT-DAY DISCUSSION:	15 MINUTES
TIME PER SECTION (*Timing may vary depending on class ability*):	60-90 MINUTES

FLORIDA STANDARDS:

SC.912.E.7.5
Predict future weather conditions based on present observations and conceptual models and recognize limitations and uncertainties of such predictions.

SC.912.E.7.8
Explain how various atmospheric, oceanic, and hydrologic conditions in Florida have influenced and can influence human behavior, both individually and collectively.

SC.912.L.17.4
Describe changes in ecosystems resulting from seasonal variations, climate change and succession.

MAFS.K12.MP.4.1
Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace.

SC.912.L.17.20
Predict the impact of individuals on environmental systems and examine how human lifestyles affect sustainability.

STUDENTS BY THE END OF THE LESSON SHOULD BE ABLE TO:

Describe how climate change causes sea level rise.
Determine the projected sea level rise for their location in South Florida.
Show how sea level rise affects the hydrological cycle and vice versa.
Identify various impacts on water quality due to sea level rise.
Describe how these negative impacts could affect our health/ the ecosystem.
Synthesize recommendations on how humans can help slow down sea level rise.

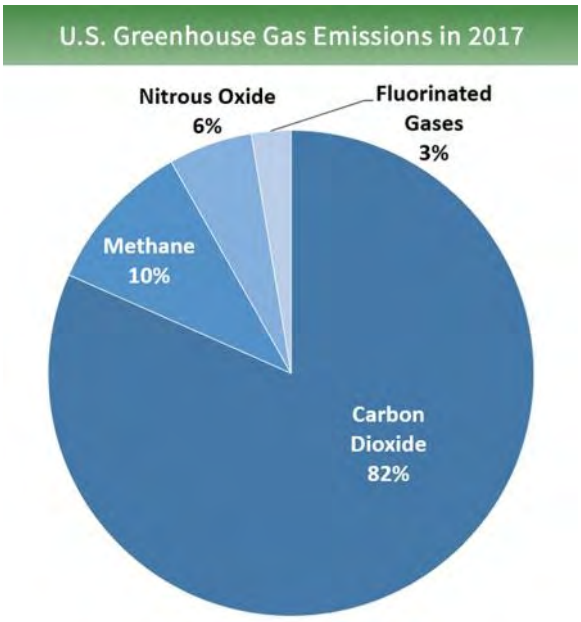
SECTION 1: INTRODUCTION TO CLIMATE CHANGE

BACKGROUND

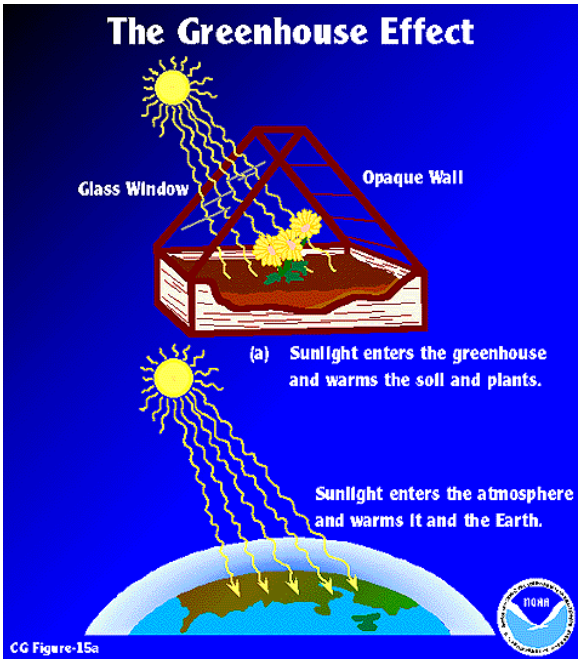
Climate change is a change in global or regional climate patterns. The impacts of a changing climate can be seen through increased temperatures, droughts, flooding, stronger hurricanes, sea level rise, and changes in precipitation, all of which have their own collection of damaging ripple effects on landscapes across the world. In order to understand how our climate here in South Florida is changing, first we need to understand its underlying causes.

The world's **atmosphere** contains a collection of gases including carbon dioxide, methane, and nitrous oxide, that makes life on Earth possible. The atmosphere operates much like a greenhouse. Greenhouses function by allowing heat and light to enter its glass walls, warm up the air and plants inside, and continue to keep the space warm because of the walls' ability to trap the light and heat within. This same process happens on our planet with the atmosphere acting as the glass walls. These planetary "glass walls" are actually a collection of gasses commonly referred to as **greenhouse gasses**.

Earth's atmosphere naturally contains these greenhouse gasses, and without them life wouldn't exist. Greenhouse gasses can be produced by humans too. For example, burning fossil fuels and raising agricultural livestock can contribute to more greenhouse gasses entering the atmosphere, like carbon dioxide from cars and methane from cattle raising. Increased greenhouse gasses means increased ability for the Earth to trap heat, gradually heating up the climate, or the average weather in a place over many years. Why does the heating up of the **climate** and the oceans matter? With this added heat, we have seen increased ocean evaporation cause stronger storms, droughts and floods are becoming more intense and widespread, glacial ice sheets have started to melt, and overall the world's climate is becoming more extreme.



GREENHOUSE EMISSIONS FOR THE UNITED STATES IN 2017 (SOURCE: UNITED STATES EPA)



THE HYPOTHETICAL GREENHOUSE EFFECT (SOURCE: HTTPS://WWW.ESRL.NOAA.GOV/GMD/EDUCATION/LESSON_PLANS/)

In order to combat climate change one must look at what systems emit greenhouse gasses and what systems absorb them. Common systems that emit greenhouse gasses in order of the amount they produce are the following:

1. Transportation, like cars, trucks, ships, and planes
2. Electricity production from burning fossil fuels like coal and natural gas
3. Agriculture, like raising livestock such as cattle who emit methane from their waste

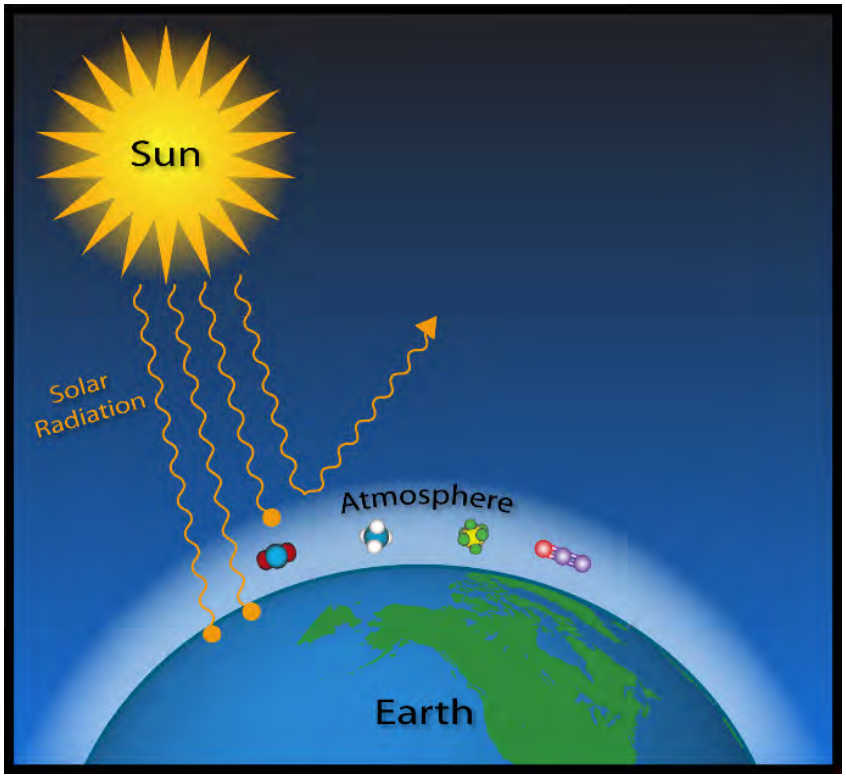
Systems that help combat these emissions by acting as carbon sinks are listed in the order of the amount they "sink" or absorb:

1. The ocean, **absorbing more than a quarter of all human's carbon dioxide emissions**
2. Forests and land-based plants

As we can see, there are many sources creating and absorbing these gasses, but the creation of these gasses is starting to outweigh the absorption. Recommendations to reduce greenhouse gas emissions are listed here:

- Drive your car and travel via plane less frequently
- Ride bikes and public transit when possible
- Advocate for cleaner and/or renewable sources of energy, like solar or wind, as compared to traditional forms of coal burning

In terms of fighting back against greenhouse gasses already created, there is one recommendation everyone can get behind: conserve and preserve our forests and oceans. Algae in the ocean and plants on land, like trees, absorb **carbon dioxide**, the most abundant greenhouse gas, and use it for a process called photosynthesis, ultimately creating oxygen as a byproduct. The more forests and healthy water bodies we either conserve or help build, the more carbon dioxide that will be captured.



EARTH'S ATMOSPHERE EXPLAINED (SOURCE: HTTPS://WWW.ESRL.NOAA.GOV/GMD/OUTREACH/CARBON_TOOLKIT/BASICS.HTML)

Activity 1: Please see the attached activity "Tracking South Florida Temperatures Through Time" to be completed either during class or as a take home assignment. You can send this document to your students or have it printed out before class.

SECTION 2: SEA LEVEL RISE: SOUTH FLORIDA'S FIGHT AGAINST TIME

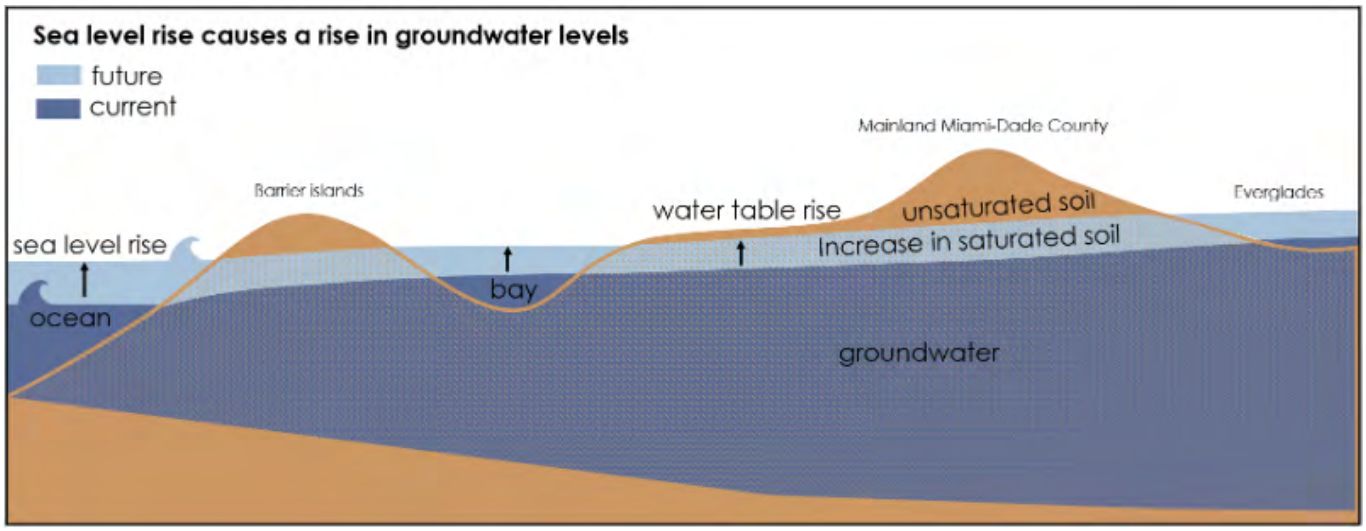
BACKGROUND

Sea level rise is a climate change phenomenon through which the ocean water volume increases and is arguably one of the worst effects of climate change due to the fact it will impact some of the most populated cities in the world, one of them being Miami here in South Florida. The rises scientists are seeing around the world are due to 1) the melting of ice sheets in the arctic and 2) **thermal expansion**.

Imagine if you were to record the initial water level in a half filled bathtub, add two buckets of ice, and then wait until the ice melted. You would see a slight increase in the water level. Besides melting ice sheets in the arctic, there is a second effect causing the seas to rise even more called thermal expansion. When water is heated up, its volume actually increases and expands. Imagine now, after the ice has melted in your bathtub and you see the slight increase in water level, you heat up your bathtub gradually. This would result in an additional rise to your water level. This is what is happening to our oceans.

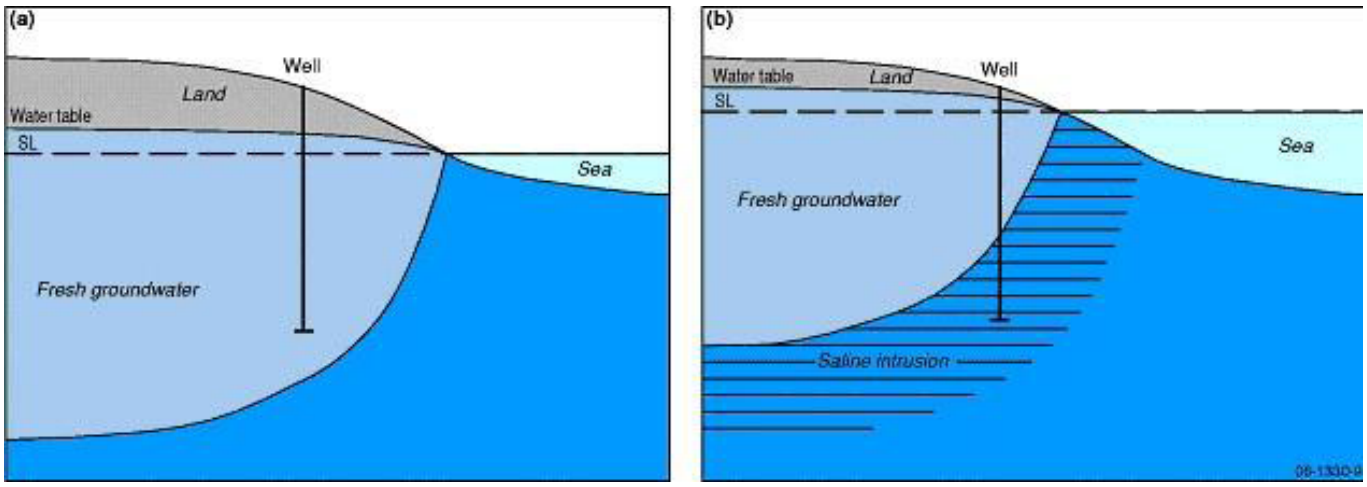
Here in South Florida, sea level rise disproportionately affects us compared to other regions of the United States and the world because of some unique geographic properties. One of these properties is that South Florida is situated on top of a rock called **limestone**. This rock is structurally very porous, like a sponge. Limestone's structure allows water to move through it relatively easily. The second property is how close to sea level most of South Florida is, some land is even situated below sea level! Both of these properties make it easy for sea level rise to have a large impact on our landscape.

When sea levels rise here in South Florida, the porous limestone we all live on top of makes it easy for the water table below the ground to shift upwards as well. The **water table** is the upper portion of groundwater nearest the land surface. Groundwater is where humans extract freshwater for drinking, irrigation, and other industrial uses. The water table is located below the ground where the soil is first saturated, or soaked through, with water. Coastal water tables stay close to sea level, showing a direct relationship between the two.



GROUNDWATER INTERACTION WITH SEA LEVEL RISE (SOURCE: MIAMI WATERKEEPER)

The amount of freshwater pulled from the ground for drinking and irrigation continues to grow with the growth in population. As seawater rises and the amount of freshwater humans in South Florida pull from the ground continues in large amounts, we start to see a phenomenon called saltwater intrusion. This is caused by decreases in groundwater levels, as well as a decreased flow from the Everglades, and/or by rises in seawater levels and causes saltwater to be drawn further inland towards freshwater zones. Saltwater intrusion threatens our freshwater supply beneath our feet and across well fields, areas we extract our drinking water from. There needs to be a good balance between how much freshwater humans are using/taking out and how much freshwater the landscape is able to recharge itself through rain and other natural sources.



EXAMPLE OF FRESHWATER WELLS GETTING IMPACTED BE SEA LEVEL RISE (SOURCE: HTTPS://OZCOASTS.ORG.AU/INDICATORS/COASTAL-ISSUES/SALINE_INTRUSION/)

When the water table rises, this creates problems for many communities further inland who reside in **low-lying areas**. These areas are prone to flooding due to the low elevation and unique geographical traits, making them particularly susceptible during major rain events and storm surge. If the water table continues to rise, then less water will be able to be absorbed into the ground, leaving the excess water with nowhere to drain.

Activity 2: Please see the attached activity "Understanding the Impacts of Sea Level Rise: An Interactive Model for South Florida" to be completed either during class or as an at home assignment.

SECTION 3: AWAKENING POLLUTION

BACKGROUND

Now that we understand climate change and, more specifically, sea level rise, we can dive into what the rippling effects are on water quality. When the sea level rises, we are seeing more events like **sunny-day flooding** and **king tides**. Sunny day flooding is caused by the change in water table due to the change in tides, causing streets and other areas to temporarily flood even without the input of rain. A king tide is an exceptionally high tide that occurs once or twice a year when the Earth, Moon, and Sun are aligned. Oftentimes king tides can show us what the future may look like as the sea continues to rise, with coastal parks, buildings, and wildlife habitats completely flooded.

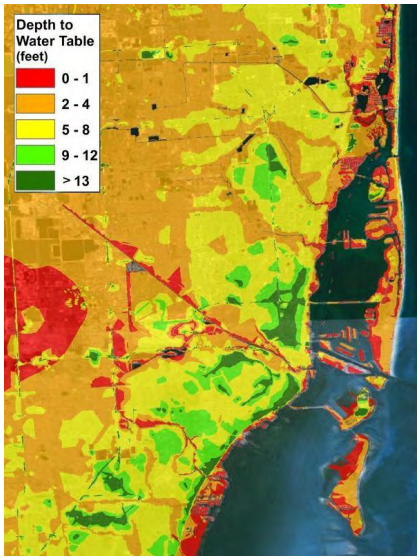
When seawater rises and gradually extends its reach further inland over time, the water comes in contact with soils potentially containing **dormant pollutants**. These dormant pollutants could be nutrients, chemicals, harmful bacteria, oil, and any other material able to be absorbed into the ground. The rise in seawater, more frequent sunny-day flooding, and higher king tides give these land-based sources of pollution another opportunity to be discharged into the surrounding water bodies via stormwater runoff. This activated pollution can lead to adverse health effects for us, like contaminated water sources and bacterial spikes, that can lead to unsafe swimming conditions and decreased availability of freshwater sources.

Increased flooding is also a problem for wastewater disposal. While much of Miami Dade County is connected to the sewer system, approximately 108,000 properties use on-site sewage treatment to dispose of their waste. This treatment is done in a **septic system**. A septic system is composed of a septic tank that collects the waste we flush down drains. The tank cleans the waste through a system separation and natural decomposers. It then allows the water to be transferred into a septic field where it is eventually filtered through dry soil. Septic tanks are not able to function in saturated, or soaked through, soils. Septic tanks can often reach as low as 8 feet below the ground's surface. When the water table rises and comes in contact with the septic tank, the sewage will not be properly treated and can contaminate the groundwater.

As you can see in the Miami-Dade Water Table Map created in 2014, many areas are already just a few feet from the water table indicating many septic tanks, about 67,000, are already being compromised!

These sources of pollution pose both threats to humans and wildlife. Activating these dormant pollutants may lead to:

1. Poor coastal water quality for swimming and recreating
2. Habitat deterioration posing threats to fisheries and important ecosystems like seagrasses.
3. Contaminated freshwater sources and saltwater intrusion



WATER TABLE DEPTH FOR MIAMI-DADE COUNTY IN 2014 (SOURCE:HTTPS://SUBMERGINGSUNSHINE.OMEKA.NET/ITEMS/SHOW/51)

Activity 3: Please see the attached worksheets "Terminology Practice" and "Reflections" to be completed either during class or as an at home assignment. You can send this document to your students or have it printed out before class.

GLOSSARY FOR TEACHER REFERENCE:

Climate Change: a change in global or regional climate patterns.

Atmosphere: the collection of gasses making up the air surrounding our planet.

Greenhouse Gasses: gasses that contribute to the greenhouse effect.

Carbon Dioxide: the most abundant greenhouse gas.

Sea Level Rise: caused by melting ice sheets and thermal expansion.

Thermal Expansion: the increase in a material's volume when it is heated up.

Saltwater Intrusion: the intrusion of saltwater into freshwater resources beneath the ground.

Water Table: the level below the ground where the soil is saturated, or soaked through, with water.

Well Field: areas of freshwater extraction for human consumption.

Sunny-day Flooding: a phenomenon when streets and landscapes may be flooded without the input of rain or runoff, usually connected with high tides.

King Tide: an extremely high tide happening once or twice a year. Good indicator for future sea level rise impacts.

Dormant Pollution: pollution that remains dormant in soils, materials, and structures on land that will be released into waterways if activated by rising seas.

Septic Systems: a self-contained, underground wastewater treatment system for Wastewater. Impacted greatly by the rise in water table levels, poses risks to contaminating soils and groundwater.

ACTIVITY 1: GRAPHING TEMPERATURES FOR SOUTH FLORIDA THROUGH TIME

Name: _____ Date: _____ Class: _____

Graphing temperatures for Southeast Florida Cities from 1980-2019

Please choose the nearest city to you that has data starting in 1980, not all cities on the website have data. Recommendations (as shown on website): Miami Area, West Palm Beach Area, Fort Lauderdale, FL, Hialeah, FL, Miami Beach, FL, Miami International AP (Be careful, Area is different than cities with FL)

Please note: You will be completing questions 1-4 ***four times****. Ensure you have all worksheets*

1. Go to https://w2.weather.gov/climate/xmacis.php?wfo=mfl and 1) select your South Florida city, 2) choose Monthly Summarized Data for Product, and then 3) choose 1980-1989 for year range, Avg temp for Variable, and Mean for Summary. Use the Average Annual Temperature in F^{o}.

Year	Average Annual Temp
1980	
1981	
1982	
1983	
1984	
1985	
1986	
1987	
1988	
1989	
TOTAL	

2. Divide the total by 10. The Average Annual Temperature from 1980 to 1989 was _____

3. Graph the results obtained in Question 1.

(F^{o})										
Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989

1. Go to https://w2.weather.gov/climate/xmacis.php?wfo=mfl and 1) select your South Florida city, 2) choose Monthly Summarized Data for Product, and then 3) choose 1990-1999 for year range, Avg temp for Variable, and Mean for Summary. Use the Average Annual Temperature in F^{o}.

Year	Average Annual Temp
1990	
1991	
1992	
1993	
1994	
1995	
1996	
1997	
1998	
1999	
TOT AL	

2. Divide the total by 10. TheAverage Annual Temperature from 1990 to 1999 was _____

3. Graph the results obtained in Question 1.

(F^{o})										
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999

1. Go to https://w2.weather.gov/climate/xmacis.php?wfo=mfl and 1) select your South Florida city, 2) choose Monthly Summarized Data for Product, and then 3) choose 2000-2009 for year range, Avg temp for Variable, and Mean for Summary. Use the Average Annual Temperature in F^{o}.

Year	Average Annual Temp
2000	
2001	
2002	
2003	
2004	
2005	
2006	
2007	
2008	
2009	
TOT AL	

2. Divide the total by 10. The Average Annual Temperature from 2000 to 2009 was _____

3. Graph the results obtained in Question 1.

(F^{o})										
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009

1. Go to https://w2.weather.gov/climate/xmacis.php?wfo=mfl and 1) select your South Florida city, 2) choose Monthly Summarized Data for Product, and then 3) choose 2010-2019 for year range, Avg temp for Variable, and Mean for Summary. Use the Average Annual Temperature in F^{o}.

Year	Average Annual Temp
2010	
2011	
2012	
2013	
2014	
2015	
2016	
2017	
2018	
2019	
TOT AL	

2. Divide the total by 10. The Average Annual Temperature from 2010 to 2019 was _____

3. Now graph the average temperatures for each set of years rounded to the nearest 0.5 increment by placing an x in each box. Notice the trend.

(F^{o})				
78.0				
77.5				
77.0				
76.5				
76.0				
75.5				
75.0				
74.5				
74.0				
73.5				
73.0				
Years	1980-1989	1990-1999	2000-2009	2010-2019

4. Every city is impacted differently when the climate changes; some places get hotter while some may get cooler. After graphing temperatures for the city closest to you, does the trend go up, down, or does it fluctuate? Compare just 1980-1989 and 2010-2019 averages, does it go up? What conclusions can you draw?

ACTIVITY 2: UNDERSTANDING THE PROJECTIONS OF SEA LEVEL RISE

Name: _____ Date: _____ Class: _____

An Interactive Model for South Florida

Materials Needed

- Computer with internet access

PART 1

A common misconception with sea level rise is it will affect every city the same way. This isn't the case however. The ocean surface is not at the same height throughout the planet, just like mountains and valleys change the altitude on land. The ocean being higher and lower in some places is due to geography, tides, winds, and currents. These differences mean that certain regions of the world can be more disproportionately affected by sea level rise.

Go to https://tidesandcurrents.noaa.gov/sltrends/sltrends.html to compare sea level rise projections for South Florida cities with other parts of the United States or the world.

Click on the colored arrows in the map and then click "Regional Scenarios." You will see the many different possibilities regarding a specific area's potential for experiencing sea level rise. This chart helps depict the **uncertainty** scientists have when estimating sea level rise. Some projections may say only ½ a meter rise in 100 years and some may even project a 3-5 meter rise. These different projections and models for sea level rise can make it hard to estimate and plan for impacts.

In 2-3 paragraphs, explain the current projected sea level rise for your South Florida city compared to that of two cities: Manila, Philippines in Asia and Anchorage, Alaska in the United States. Make sure to answer the following:

- What is the total sea level rise projected in 2100 for your city? How may it affect this region in your lifetime?
- What are the projected sea level rises of the other two cities listed? What are the interesting differences?
- How might their location impact them differently than South Florida? (Think about population sizes or land use)
- What are your thoughts about scientific uncertainty by using the "Regional Scenarios"? How do you think we can reduce uncertainty?

PART 2

In Part 1, you determined the projected sea level rise for your South Florida city. Convert that level from meters to feet. You may realize sea levels are projected to rise between 1-2 feet over the next century for South Florida. Go to https://mdc.maps.arcgis.com/apps/webappviewer3d/index.html?id=b92a9fa4ff8847bf97f3e628a195a398 to view a 3D interactive map to see how these slight changes to sea level rise could impact many buildings and communities using Miami-Dade County as an example. Test out a couple different projections.

Write a short 2-4 sentence summary of what you conclude about the different sea level rise projections. Also take a look further inland at the low-lying areas, flood prone locations, shaded in green. Is there still an effect at the 1 or 2-foot rise in sea level? Are we prepared for other possibilities of larger increases?

ACTIVITY 3: TERMINOLOGY PRACTICE WORKSHEET

Name: _____ Date: _____ Class: _____

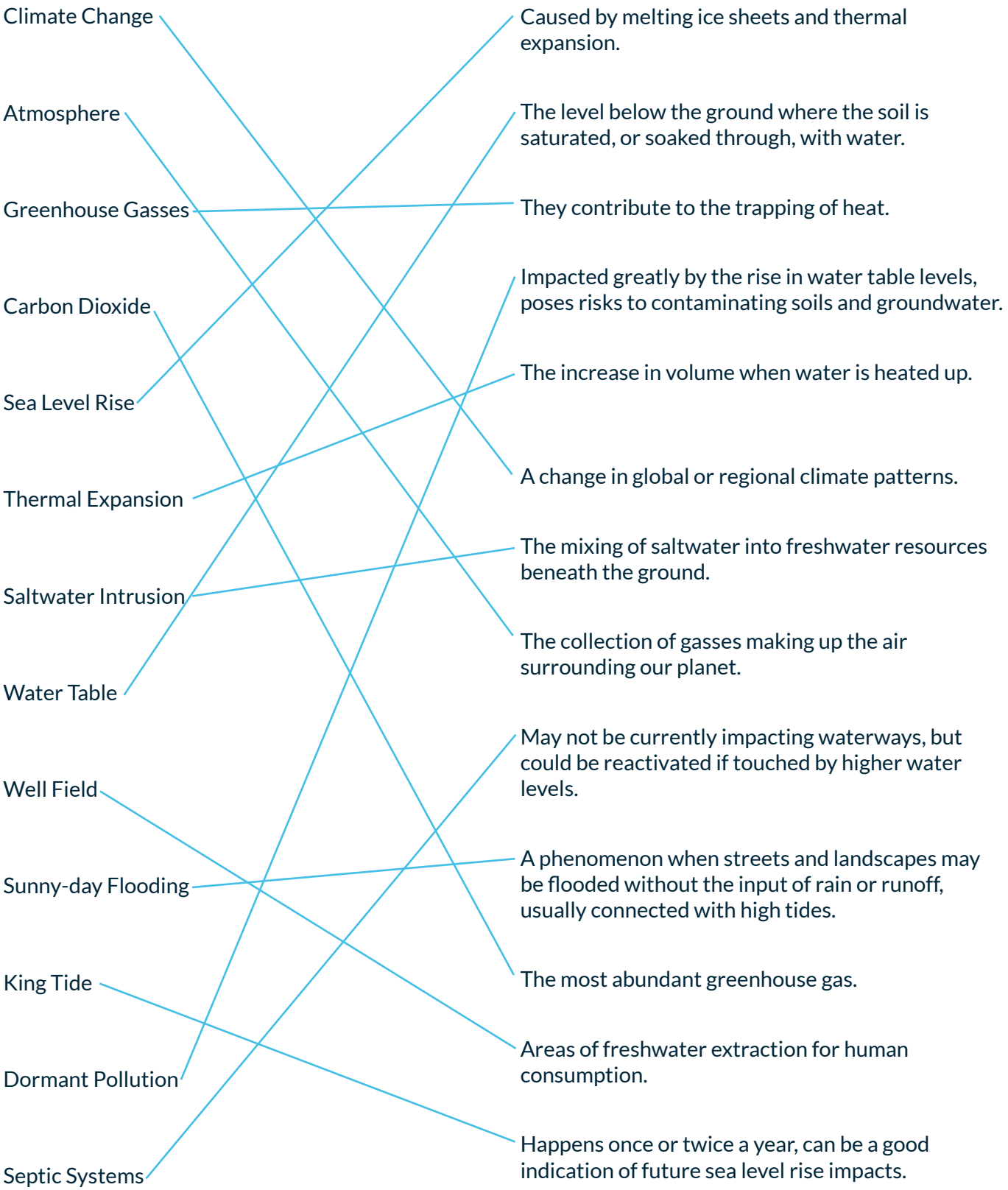
Match the term with the definition it most closely represents by drawing a line.

Climate Change	Caused by melting ice sheets and thermal expansion.
Atmosphere	The level below the ground where the soil is saturated, or soaked through, with water.
Greenhouse Gasses	They contribute to the trapping of heat.
Carbon Dioxide	Impacted greatly by the rise in water table levels, poses risks to contaminating soils and groundwater.
Sea Level Rise	The increase in volume when water is heated up.
Thermal Expansion	A change in global or regional climate patterns.
Saltwater Intrusion	The mixing of saltwater into freshwater resources beneath the ground.
Water Table	The collection of gasses making up the air surrounding our planet.
Well Field	May not be currently impacting waterways, but could be reactivated if touched by higher water levels.
Sunny-day Flooding	A phenomenon when streets and landscapes may be flooded without the input of rain or runoff, usually connected with high tides.
King Tide	The most abundant greenhouse gas.
Dormant Pollution	Areas of freshwater extraction for human consumption.
Septic Systems	Happens once or twice a year, can be a good indication of future sea level rise impacts.

ACTIVITY 3: TERMINOLOGY PRACTICE WORKSHEET

Name: ANSWER KEY Date: XXXX Class: XXXX

Match the term with the definition it most closely represents by drawing a line.



After using this lesson plan, we would love for you to write a short review using the following link to access a survey:
Click here to review this lesson plan!

Your responses will help make these resources and future ones better!