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Module Outline

- Introduction to climate change and sea level rise
- Overview of our climate system and evidence of our changing climate
- Overview of greenhouse gases and their impact
- “What is the impact?”
- “Drivers” of climate change and their effects on Florida’s ocean and coastal resources
- Making choices in the face of risk



Module Goals

- Learning Goals
 - To advance environmental literacy and civic engagement in environmental issues
 - To understand the significance of climate change and sea level rise and the consequences we may have to face as a result
 - To understand which drivers are having the most detrimental environmental impacts
 - To gain insight to what is being done to mitigate and adapt to our dynamic environment



Module Goals



Image source: Libby Carnahan

- Action Goals

- Identify ways you can live a more sustainable lifestyle
- Share your knowledge and concerns with local decision-makers
- Participate in citizen monitoring efforts



Introduction

- Widely accepted that human activities can impact global climate patterns
- Can't predict all aspects of climate change that might affect Florida's natural resources and economy
- Because of these potential risks, we need to understand how our activities impact the environment



Climate Change

- Defined as a change in the climate
 - identifiable by changes in the mean and/or the variability of its properties, that
 - are averaged over several decades (i.e., 30 years)
- Refers to any change in climate over time whether caused by natural variability or human activity



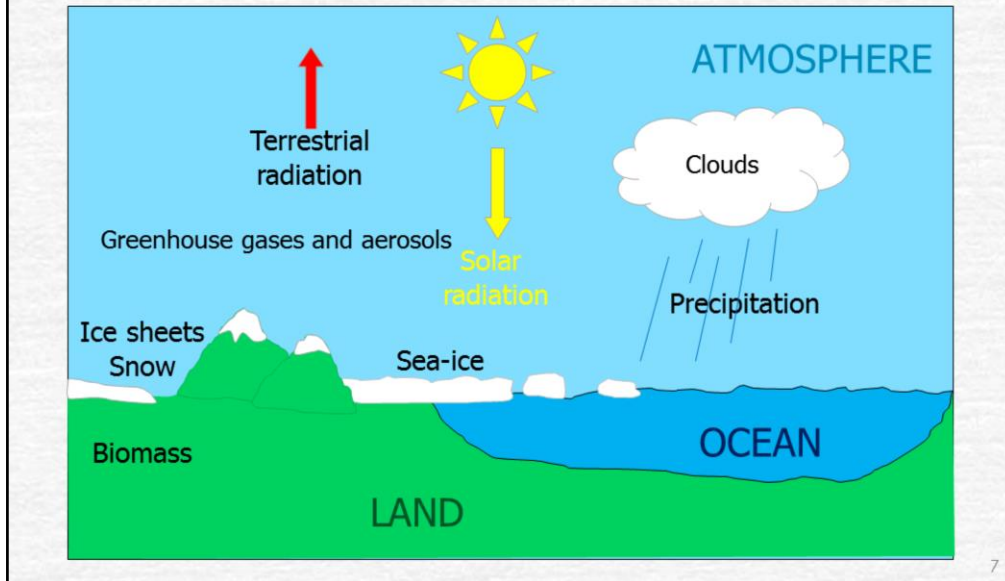
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Climate - the long-term **average**, **variation**, and **extreme** conditions of weather. The World Meteorological Organization defines “long-term” as 30 years.

Climate is perceived mostly in terms of **temperature** and **precipitation**, local and global.

Climatology - the science of climate; studies climate variation and its causes.

Components of the Climate System



The **atmosphere**: its circulation, the heat (terrestrial radiation) and light (solar radiation) which pass through it, and the processes which go on in it, such as the formation of clouds and the **atmospheric chemical reactions** that determine the concentrations of some of its important constituents, such as methane and ozone.

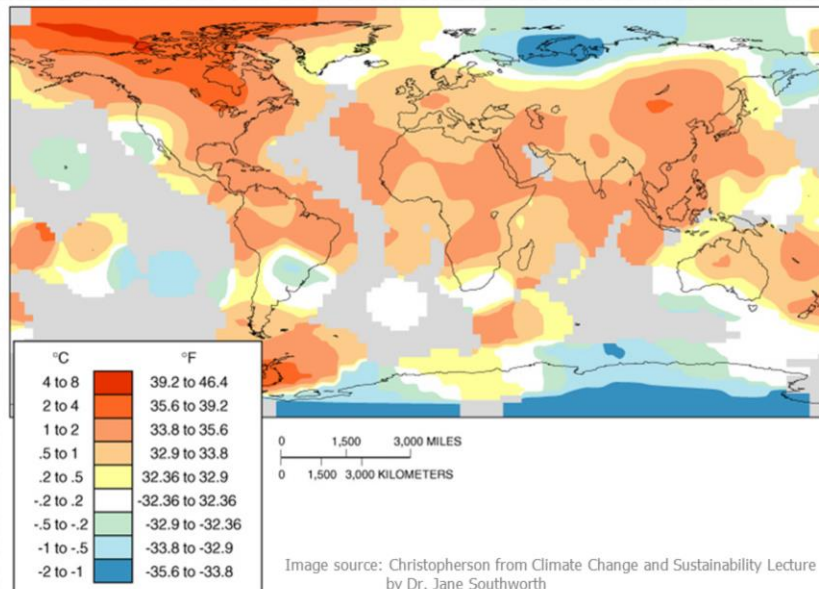
The **ocean**: there is a constant exchange of heat, momentum and water between ocean and the atmosphere. The ocean acts as a heat sink. In addition, ocean currents transport large amounts of heat and water around the world.

The **land surface**, including its vegetation and seasonal snow cover, has an important influence on the flow of air over it, the absorption of solar energy, and the water cycle.

The **cryosphere**: those parts of the world whose surface is affected by ice, principally **sea-ice** in the Arctic and Southern Oceans and the **land-based ice-sheets** of Greenland and Antarctica.

The **biosphere**: life on land (the **terrestrial biosphere**) and in the ocean (the **marine biosphere**) play a major role in the **carbon cycle** and hence in determining the atmospheric concentration of carbon dioxide.

Geographic Global Air Temperature Variation



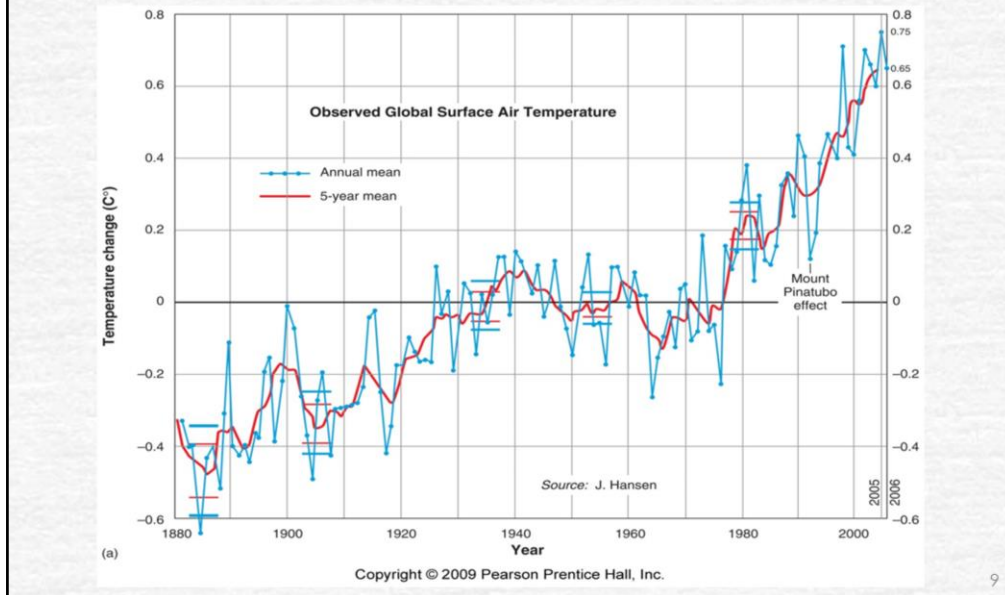
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Climate varies with **location**.

- Global mean surface (air) temperature increased by $0.74^{\circ}\text{C} \pm 0.18^{\circ}\text{C}$ from 1906–2005.
- Eleven of last twelve years (1995-2006) rank among 12 warmest years on record since 1850.
- Cold areas getting colder, warm areas getting warmer

Image source: Christopherson from Climate Change and Sustainability Lecture by Dr. Jane Southworth

Global Air Temperature Variation Through Time



Climate also varies through **time**.

- This, for example, is the temperature of the Earth as observed by averaging data from several thousand weather stations around the globe.
- The dots are annual means (averages), while the red line is called a 5-year moving mean,* used to smooth the inter-year variation and expose general trends. The 0 line is the 1950-1980 global average.
- So, temperature, and by extension climate, hasn't been stable over the 20th century. What has happened? This question brings up the larger one of what factors drive climate, and how do the factors behave over time?

* A **moving mean** is a set of numbers, each one the average of a subset from a larger collection of data points. It is calculated by taking the average of the initial subset of data points. Then the subset is modified by “shifting forward”: removing the first number of the series and adding in the next number following the original subset in the series. This creates a new subset of numbers, which is averaged, and the process is repeated over the entire data series. The plot line connecting all the (fixed) averages is the moving mean.

Image source: Christopherson from Climate Change and Sustainability Lecture by Dr. Jane Southworth

Climate Change

- Questions we need to ask ourselves
 - How long do greenhouse gases stay in the atmosphere?
 - How much will temperatures continue to rise and at what rate?
 - What consequences can we expect to face as a result and at what rate we will experience them?



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It is vital to also realize how oceans help by acting as a reservoir for dissolved carbon dioxide and are critical in their ability to absorb, retain, and distribute heat. Recent reports indicate that deep ocean water is warming faster than ever before—showing that the ocean is acting as a heat sink even if air temperatures do not seem to be increasing.

Human activities such as burning of fossil fuels and deforestation lead to these environmental changes: rising sea levels, ice melting, increased temperatures

Greenhouse gases stay in the atmosphere for hundreds of years so we are only seeing the effects of actions that took place in the past. What kind of impacts will our current actions have? We will see the consequences for years to come. Ocean acidification (resulting from the ocean's dissolution of atmospheric carbon dioxide) is one of these impacts.

Consequences we may experience due to rising temps: coral bleaching, species range shifts, diseases, changes in precipitation patterns. What could the long term effects of these changes bring?

Greenhouse Gases (GHGs)



- Present in the Earth's atmosphere
- Produced both naturally and by industrial processes







Image source:
<http://www.floridaoceanscouncil.org/>

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Greenhouse Gases (GHGs)

- Responsible for absorbing and emitting heat (or infrared radiation) from the planet's surface, atmosphere and clouds
- Crucial in maintaining the Earth's temperature
- Excess quantities that are trapped within the atmosphere cause temperatures to rise

The most common GHGs are: water vapor, carbon dioxide (CO₂), methane (CH₄), and ozone. Other GHGs include nitrous oxide (N₂O), perfluorocarbons, and chlorofluorocarbons. Of all the greenhouse gases, CO₂ is the most abundant in the atmosphere.

Primary GHGs and sources:

- CO₂ – Fossil-fuel use and land-use change (deforestation)
- CH₄ – Agriculture and fossil-fuel use
- N₂O – Agriculture
- H₂O – water vapor concentration in the atmosphere is not directly controlled by human activities, but is controlled by temperature.

—Source: Intergovernmental Panel on Climate Change (IPCC)
Fourth Assessment Report, *Climate Change 2007*

CO₂ levels:

- Currently, about 385 parts per million (ppm), whereas pre-industrial levels were 270 ppm. This is a 42% increase.
- IPCC projects increases up to 600 ppm by 2100 under business-as-usual conditions.
- Current levels of CO₂ are higher than any time in previous 650,000 years.

Image source: Florida Oceans and Coastal Council <http://www.floridaoceanscouncil.org/>

The Greenhouse Effect

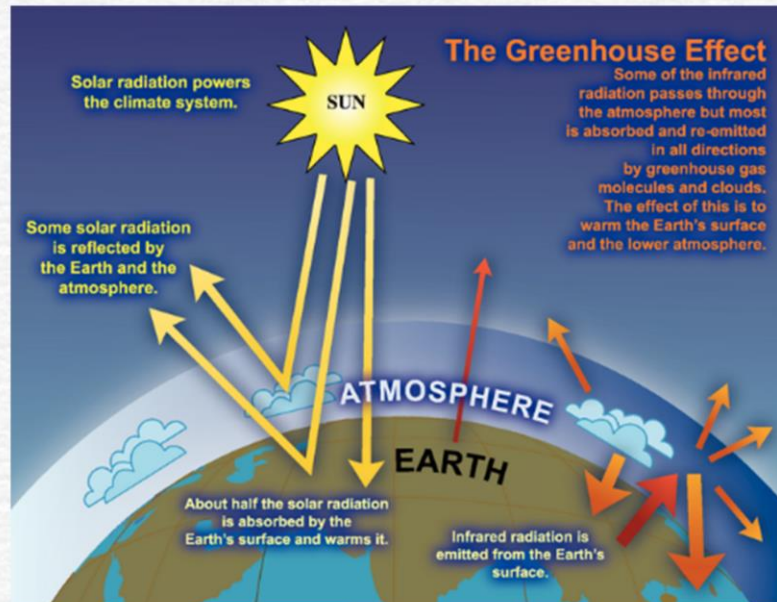


Image source: Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report: *Climate Change 2007*

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Greenhouse Effect

When the sun's energy hits the Earth, some of it is reflected back to space, but a large amount is absorbed by the land and oceans, which is then radiated upward from the Earth's surface in the form of heat. The naturally occurring greenhouse gases (carbon dioxide, methane, nitrous oxide, and water vapor) absorb and redirect some of this energy back down to the Earth. With the increase of greenhouse gases in the atmosphere a higher amount of this infrared energy is being absorbed and redirected back to the Earth's surface, causing temperatures to increase.

Note that recent evidence is that the Earth is now maintaining 2 watts/meter of heat more than it is emitting into space. (Jim Hansen, 2009. *Storms of my Grandchildren*).

Image source: IPCC Fourth Assessment Report: Climate Change 2007, Working Group I: The Physical Science Basis. Chapter 1, Historical Overview of Climate Change Science, FAQ 1.3: "What is the Greenhouse Effect?"

http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-1-3.html

- Yellow line = direct solar irradiation energy flows
- Red lines = infrared reflected energy flows

The Cost of Carbon

- The Cost of Carbon
- <http://www.youtube.com/watch?v=za4r5uWj4AY> (3:26 minutes)



To open the videos, place your cursor anywhere in the link and right click. When the drop-down menu appears, choose **Open Hyperlink**. Or, copy the link and paste it into your browser.

Length of video – 3:26 minutes

What is the impact?

- Florida is especially vulnerable to the effects of global warming since it has many resources that serve both ecological functions and as recreational opportunities.







Image source: http://sanctuaries.noaa.gov/pgallery/pgflorida/living/living_20.html



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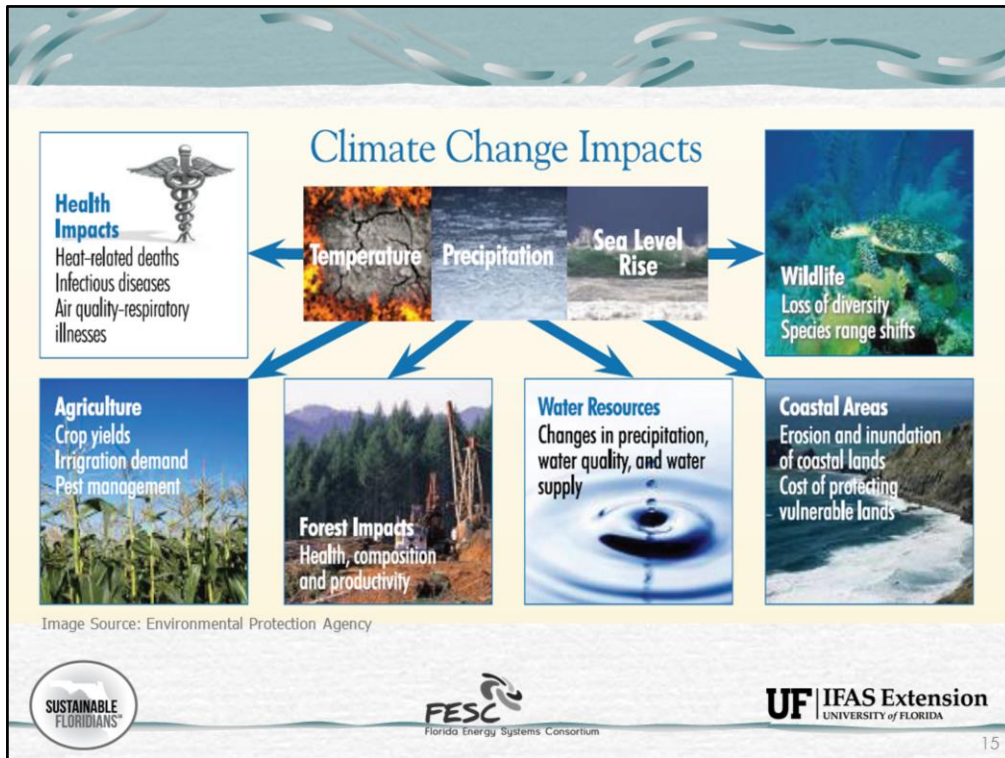
This slide serves as a foundation for further discussions of the effects of global climate change on Florida’s ocean and coastal resources.

Florida is especially vulnerable to the effects of climate change:

- Over 1,200 miles of coastline
- 4,500 square miles of estuaries and bays
- More than 6,700 square miles of coastal waters
- Maximum elevation less than 400 ft above sea level
- Many Floridians reside within 60 miles of the coast.
- Diverse ecosystems that support a vast number of aquatic and terrestrial animals and plants, some of which are endemic to the natural ecosystems here, or are endangered due to the loss and degradation of habitat in which they reside.
- Overall, ocean and coastal resources are Florida’s life support system and economy—food resources, aesthetics (tourist), etc.

Vulnerability of the Florida Keys:

- The Keys are a low-lying archipelago 120 miles long, composed of limestone rock, with a maximum height above sea level of about 18 feet.
- 72,000 people; more than 53,000 housing units
- The Keys will have to deal with climate change long before most of the rest of the U.S.



Climate change will affect different regions, ecosystems, and sectors of the economy in many ways, depending not only on the sensitivity of those systems to climate change, but also on their ability to adapt to risks and changing conditions. Throughout history, societies and ecosystems alike have shown remarkable capacity to respond to risks and adapt to different climates and environmental changes. Today, effects of climate change have already been observed, and the rate of warming has increased in recent decades.

For this reason, human-caused climate change represents a serious challenge—one that could require new approaches and ways of thinking to ensure the continued health, welfare, and productivity of society and the natural environment.



Ocean acidification refers to a reduction in the pH of the ocean over an extended period of time, caused primarily by uptake of carbon dioxide (CO₂) from the atmosphere.

For more than 200 years, or since the industrial revolution, the concentration of CO₂ in the atmosphere has increased due to the burning of fossil fuels and land use change. The ocean absorbs about 30 percent of the CO₂ that is released in the atmosphere, and as levels of atmospheric CO₂ increase, so do the levels in the ocean.

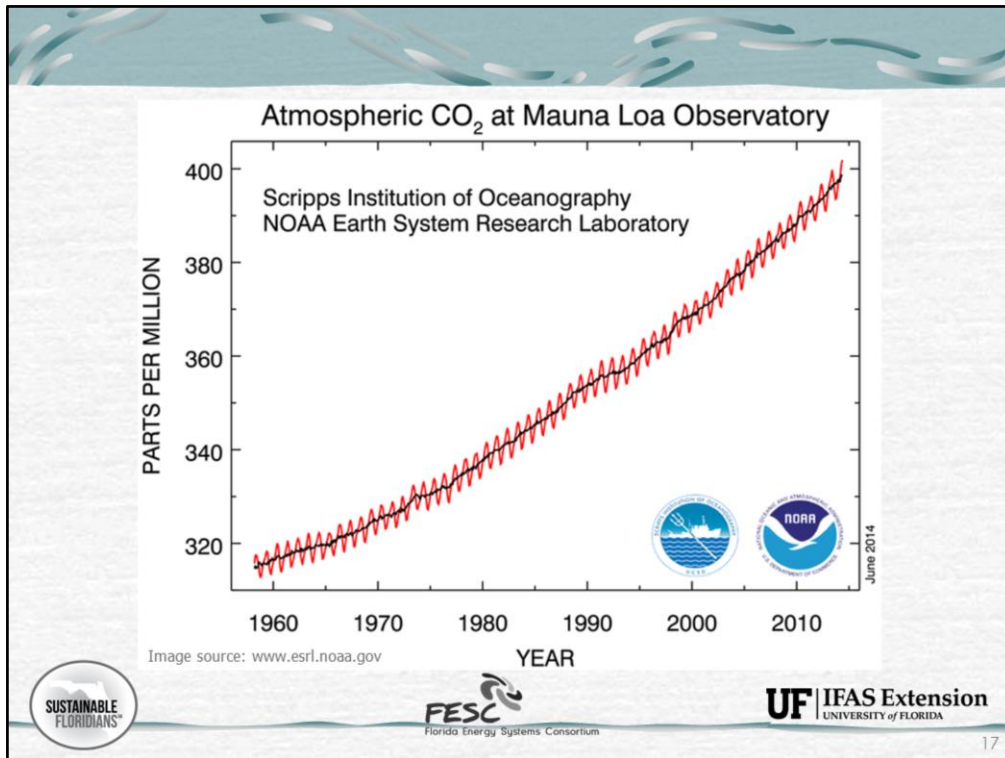
When CO₂ is absorbed by seawater, a series of chemical reactions occur resulting in the increased concentration of hydrogen ions. This increase causes the seawater to become more acidic and causes carbonate ions to be relatively less abundant.

Carbonate ions are an important building block of structures such as sea shells and coral skeletons. Decreases in carbonate ions can make building and maintaining shells and other calcium carbonate structures difficult for calcifying organisms such as oysters, clams, sea urchins, shallow water corals, deep sea corals, and calcareous plankton.

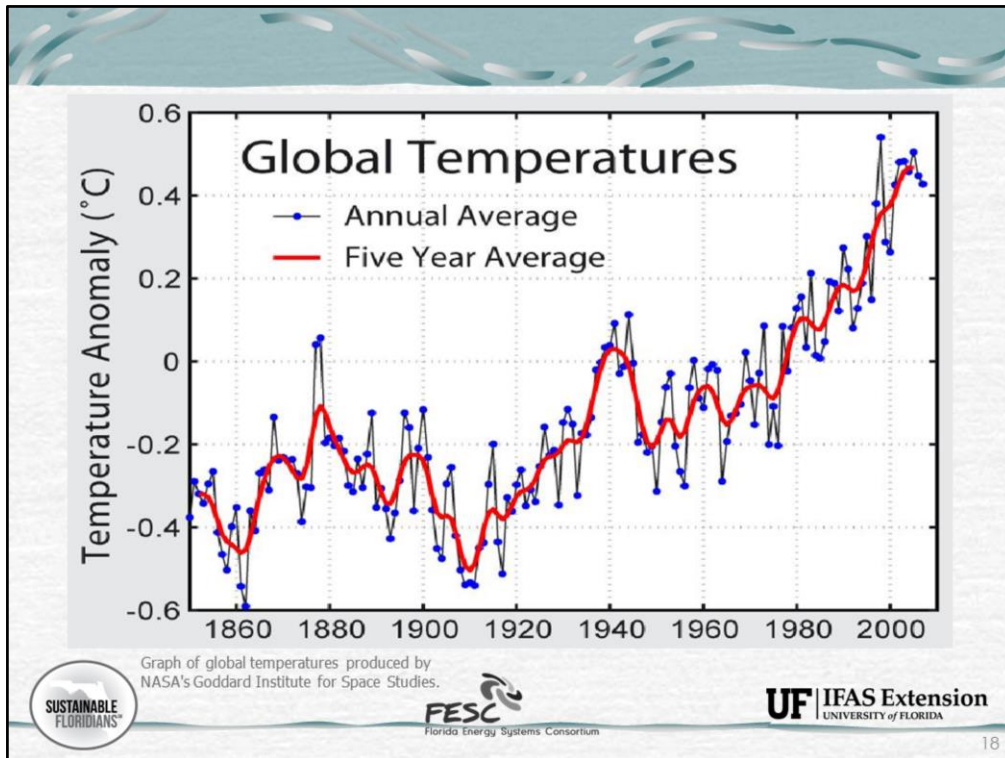
These changes in ocean chemistry can affect the behavior of non-calcifying organisms as well. Certain fishes' ability to detect predators is decreased in more acidic waters. When these organisms are at risk, the entire food web may also be at risk.

Ocean acidification is affecting the entire world's oceans, including coastal estuaries and waterways. Many economies are dependent on fish and shellfish and people worldwide rely on food from the ocean as their primary source of protein.

Image on bottom: Pteropods are small calcifying (or shelled) organisms that live as zooplankton in the water column and are an important prey species for many fish. Changes in ocean chemistry can break down their calcium carbonate shell, ultimately leaving the marine food web at risk.




The 20th century temperature increase is mostly caused by increased concentrations of greenhouse gases from human activities. Carbon dioxide, for example, is produced naturally but is also generated by deforestation and the burning of fossil fuels.



Note the dramatic change in temperature over the last 150 years.

We are becoming alarmingly aware that warming of the Earth's climate system is unequivocally taking place, and most of the temperature increase is likely caused by increased concentrations of greenhouse gases.

What is the impact?



With increased water and atmospheric temperatures, conditions will become increasingly favorable for the invasion of exotic plant and animal species in Florida and surrounding coastal waters.

Image Source: www.reef.org

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Source: White House press release, May 6, 2014. Fact Sheet: “What Climate Change Means for Florida and the Southeast and Caribbean.” Third U.S. National Climate Assessment. http://www.whitehouse.gov/sites/default/files/docs/state-reports/FLORIDA_NCA_2014.pdf

Selected Findings and Information from the Third U.S. National Climate Assessment Relevant to FLORIDA

- **Tribes:** “Tribal communities in Florida are facing potential displacement due to the risk of rising sea levels and saltwater intrusion inundating their reservation lands.” (NCA, Ch. 12: Indigenous Peoples)
- **Tourism:** “Climate change impacts on tourism and recreation will vary significantly by region. For instance, some of Florida’s top tourist attractions, including the Everglades and Florida Keys, are threatened by sea level rise, with estimated revenue losses of \$9 billion by 2025 and \$40 billion by the 2050s.” (NCA, Ch. 14: Rural Communities)
- **Health:** “Atlanta, Miami, New Orleans, and Tampa have already had increases in the number of days with temperatures exceeding 95°F, during which the number of deaths is above average. Higher temperatures also contribute to the formation of harmful air pollutants and allergens. Ground-level ozone is projected to increase in the 19 largest urban areas of the Southeast, leading to an increase in deaths.” (NCA, Ch. 17: Southeast)
- **Sea Level Rise:** “Sea level rise presents major challenges to South Florida’s existing coastal water management system due to a combination of increasingly urbanized areas, aging flood control facilities, flat topography, and porous limestone aquifers. For instance, South Florida’s freshwater well field protection areas lie close to the current interface between saltwater and freshwater, which will shift inland with rising sea level, affecting water managers’ ability to draw drinking water from current resources. Coastal water control structures that were originally built about 60 years ago at the ends of drainage canals to keep saltwater out and to provide flood protection to urbanized areas along the coast are now threatened by sea level rise.” (NCA, Ch. 17: Southeast)
- **Water:** “The Apalachicola-Chattahoochee-Flint (ACF) River basin in Georgia, Alabama, and Florida supports a wide range of water uses and the regional economy, creating challenging water sharing tradeoffs for the basin stakeholders. Climate change presents new stresses and uncertainties. ACF stakeholders are working to develop a management plan that balances economic, ecological, and social values.” (NCA, Ch. 3: Water)
- **Flooding:** “There is an imminent threat of increased inland flooding during heavy rain events in low-lying coastal areas such as southeast Florida, where just inches of sea level rise will impair the capacity of stormwater drainage systems to empty into the ocean. Drainage problems are already being experienced in many locations during seasonal high tides, heavy rains, and storm surge events. Adaptation options that are being assessed in this region include the redesign and improvement of storm drainage canals, flood control structures, and stormwater pumps.” (NCA, Ch. 17: Southeast)
- **Ecosystems:** “Coral reefs in the Southeast and Caribbean, as well as worldwide, are susceptible to climate change, especially warming waters and ocean acidification, whose impacts are exacerbated when coupled with other stressors, including disease, runoff, over-exploitation, and invasive species.” (NCA, Ch. 17: Southeast)

What is the impact?

- Based on current scientific knowledge, we know the following scenarios are probable due to rising sea levels:
 - Flooding
 - Salt water intrusion
 - Erosion

Image: National Climate Assessment, Figure 17.6 , Vulnerability to Sea Level Rise
<http://nca2014.globalchange.gov/report/regions/southeast>

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Florida has a high chance of becoming more vulnerable to coastal flooding and storm surges.

Shoreline retreat and erosion is occurring.

Shallow coastal aquifers and associated public drinking water supplies are at risk from salt water intrusion and from reduced aquifer recharge.

As sea levels rise, more properties will be subject to flooding and prone to increased flood insurance costs.

Along with the shoreline retreating and erosion continuing to occur from the rising sea levels, barrier islands will also continue to erode and migrate towards the mainland.

Public water supplies for the Pensacola to Miami and Palm Beach areas are especially vulnerable.

A less visible impact of sea level rise is the increased risk of saltwater intrusion into freshwater aquifers which are used for drinking, irrigation and other purposes throughout Florida.

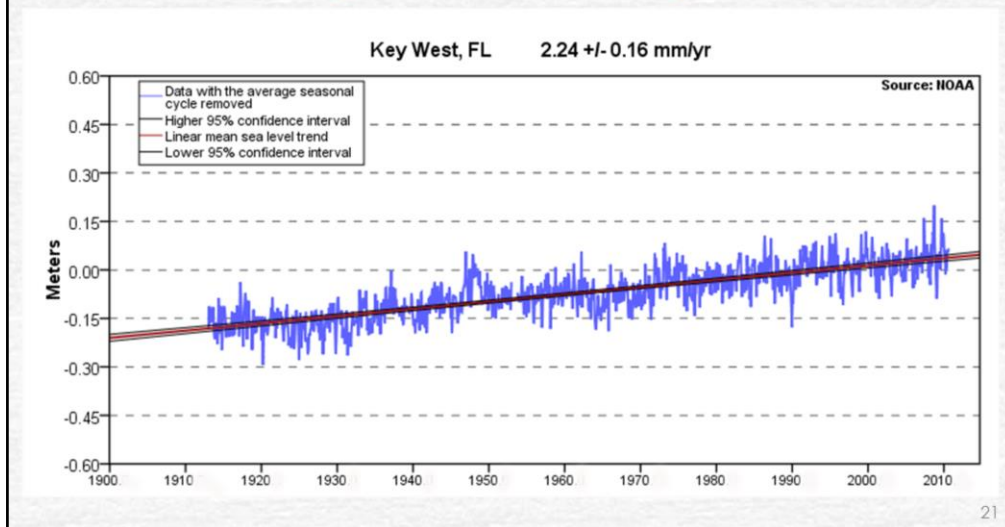
- 90% of south Florida residents get water from groundwater
- 6 out of 8 wells supplying Hallandale Beach have been shut down because of saltwater intrusion

Once saltwater has been drawn into an aquifer, it is not really possible to get rid of it. The cheapest option for dealing with the problem is to relocate the well—either sinking a shallower well, or drilling into another area of the aquifer. Over time, there will be fewer and fewer options for drilling new wells. A second option is to take the brackish well water and convert it to fresh water using a desalination plant. Once the salt has been removed, it must be disposed of, and the primary way of doing this is through deep well injection. This can be extremely costly costing up to several hundred million dollars.

http://articles.sun-sentinel.com/2011-09-12/health/fl-saltwater-intrusion-20110912_1_saltwater-intrusion-saltwater-threat-drinking-water

Image source: National Climate Assessment. Figure 17.6 , Vulnerability to Sea Level Rise
<http://nca2014.globalchange.gov/report/regions/southeast> (The red areas in the image have the greatest vulnerability to sea level rise.)

Key West Sea Level Rise (SLR) Historical Trend (1900-2010)



In past 100 years SLR = 9 inches, a rate of about 1.8 mm/yr. But in the past **10-20 years** SLR has been increasing at about 3.1 mm/yr, a 72% increase in the rate of rise.

Note: 3.1 mm/yr = 31 mm/decade = 310 mm/century or 30 cm/century

SLR occurs from ocean expansion due to warming (warmer water takes up greater volume).

Meltwater from land-based glaciers (Greenland and Antarctica): More and more, meltwater seems to be an increasing component of SLR—more than thermal expansion, which has accounted for most of the SLR to present.

In addition to ocean levels rising, the land itself can rise or sink. Subsidence (sinking of land masses) generally results from human activities, especially withdrawal of underground water. In Florida, we are familiar with sinkholes forming because of these withdrawals. On a larger scale, a more gentle “settling” of land can occur. Plate tectonics, especially where one plate is being driven beneath another one, can cause land to become elevated. Also, as glaciers melt, weight is removed from the land in some locations, allowing that land to rise.

One source of info: <http://www.arctic.noaa.gov/detect/ice-glacier.shtml>

Evidence of Climate Change and a Source of Sea Level Rise



Photograph by Maia McGuire

- Exit Glacier, near Seward, AK
- Has retreated over 7,000 feet since 1815
- An average rate of 43 feet/year



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The major contributor to sea level rise is melting land ice. On average, this has caused sea levels to rise an average of 2.5 mm/year. However, an acceleration in the rate of melting of glaciers is expected to cause global sea level to rise by about 12 cm by 2100.

Exit Glacier info from:

<http://www.nps.gov/kefj/naturescience/upload/The%20Retreat%20of%20Exit%20Glacier.pdf>

Contribution to SLR: <http://www.sciencedaily.com/releases/2011/01/110110103731.htm>

Evidence of Sea Level Rise: The Florida Keys



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We already have compelling evidence of existing sea level rise: these are examples of flooding in the Keys during the perigean high tides of 2009.

Perigean tides, as defined by NOAA (at <http://oceanservice.noaa.gov/facts/perigean-spring-tide.html>): “About three or four times a year (in the spring and the fall), the new or full moon coincides closely in time with the perigee of the moon—the point when the moon is closest to the Earth. These occurrences are often called 'perigean spring tides.' The difference between ‘perigean spring tide’ and normal tidal ranges for all areas of the coast is small. In most cases, the difference is only a couple of inches above normal spring tides.”

Image source: Photos provided by Alison Higgins, TNC, Florida Keys Office

Historically speaking...

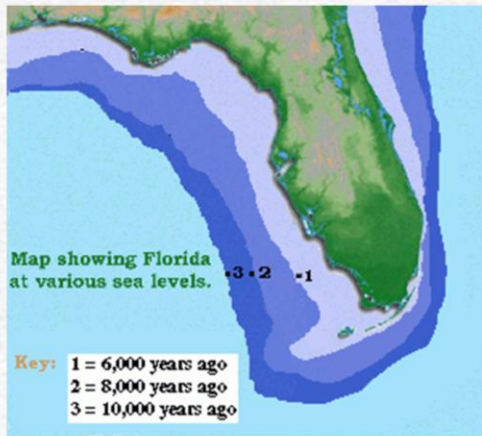


Image source: FL Dept. of State

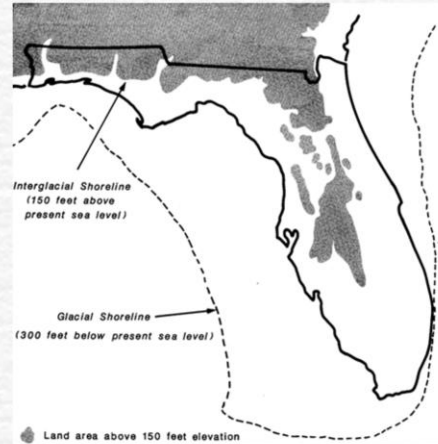


Image source: Whitney Gray, 2012

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Image 1 (on the left):

If we look back in geological time, we can see that much more of the Florida peninsula—a limestone plateau—was above sea level.




Image source: <http://www.flheritage.com/facts/reports/contexts/paleo.cfm>

Image 2 (on the right):

Much of Florida was underwater a million years ago. The gray shows the dry land 1.8 million years ago...the dotted line shows the shoreline 10,000 years ago.



- Rising sea levels threaten South Florida
- <http://video.wpbt2.org/video/2365148517/> (26 min)
- Flood-prone South Florida considers proactive investment against rising seas
- <http://www.pbs.org/newshour/bb/south-florida-rising-sea-levels/> (9 min.)



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To open the videos, place your cursor anywhere in the link and right click. When the drop-down menu appears, choose **Open Hyperlink**. Or, copy the link and paste it into your browser.

(The first link opens better in Firefox. If the link doesn't work for you, google "rising seas video wpbt2".)

What is the impact?

- Geographic range of marine species will shift northward, which could lead to drastic changes in
 - Species composition
 - Ecosystem function
- Geographic range of habitats could also shift
 - Possible threats to the ecological integrity of natural communities in estuaries, tidal wetlands, and tidal rivers



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Ecosystem function: a technical term that describes the components, such as biological, geochemical, and physical processes, all of which affect the vegetation, water, soil, atmosphere, flora and fauna (diversity). They interact with each other, thus generating a unique natural community. When one of the components no longer has an impact the community is subject to change, which can impact the ecosystem services the community provides.

Ecosystem services: processes by which the environment produces resources (i.e: timber, clean water). Other services can include:

- Mitigation of floods and droughts
- Pollination/dispersal of seeds
- Purification of air and water
- Cycling and regulation of nutrients
- Detoxification and decomposition of wastes
- All contribute to climate stability

Increasing sea-surface temperatures have led to episodic die-offs of sponges, coral species, sea grasses, and other critical components of coastal and marine ecosystems.

Impact Review

- Four major drivers of climate change:
 1. Increasing greenhouse gases
 2. Increasing air temperature and water vapor
 3. Increasing ocean temperature
 4. Increasing sea level



1. Increasing Greenhouse Gases

- Earth's temperature rising due to increasing levels of carbon dioxide and other greenhouse gases
 - Prevent atmospheric heat from escaping
- Increased by human activities such as
 - Deforestation
 - Use of fossil fuels (such as coal, oil and natural gas)
- Effect: Increases in ocean acidification



<http://soundwaves.usgs.gov/2009/11/>



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As levels of carbon dioxide in ocean waters increase, the oceans become more acidic. The average pH of the ocean has been approximately 8.2 units. A downward change in any pH value means an increase in acidity. Because the pH scale is logarithmic, a change of as little as 0.1 pH unit can have a large impact on organisms living in the sea because it represents a 30 percent increase in acidity. Since the industrial era, the average pH of the ocean has decreased to approximately 8.1 (<http://www.whoi.edu/OCB-OA/page.do?pid=112076>). Shellfish, plankton, corals, coral reefs, etc. are severely threatened by processes such as ocean acidification.

2. Increasing Air Temperature and Water Vapor

- Increasing air temperature increases the atmosphere's capacity to retain water vapor.
- Water vapor is the most abundant greenhouse gas
 - A significant factor causing uncertainty in climate prediction models and climate forecasts
- Effects:
 - Altered rainfall and runoff patterns
 - Changes in the frequency/intensity of tropical storms



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Some of the uncertainty in climate prediction models relates to:

- **Altered rainfall and runoff patterns:** Rainfall over the Florida peninsula depends on the winds (e.g., sea breezes), especially in the summer, and on hurricanes and tropical storms. Climate change, land use and other factors may result in greater variations in observed patterns, conflicting trends, and regional differences within the state. Distinguishing Florida-specific rainfall and runoff trends from future global trends is a critical research need.
- **Altered frequency and intensity of tropical storms and hurricanes:** The development of tropical storms and hurricanes depends not only on sea-surface temperature and water vapor content, but also on factors such as wind shear, which plays a significant role. Because of changes in methodology, it is difficult to obtain comparable data for tropical storms and hurricanes over the period of record, which dates from the mid-19th century.

3. Increasing Ocean Temperature

- Effects:
 - Increased coral bleaching and disease
 - Increased incidence of coral, fish and shellfish diseases



Florida is vulnerable due to its location between the Gulf of Mexico and the Atlantic Ocean.

Photographs by Ryan Moyer



<http://soundwaves.usgs.gov/2009/11/>



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Effects:

- **Increases in coral bleaching and disease:** Corals are tropical animals already living close to their upper water temperature limits. These animals have a close association with single-celled plants that live inside the cells of the coral and that provide energy to the coral by photosynthesis. Corals are said to bleach, or whiten, when they lose their plant cells. Bleaching events are correlated with local or regional increases in sea water temperature.
- **Increases in diseases, sponge die-offs, and loss of marine life:** Corals are not the only marine organisms adversely affected by increased sea-surface temperatures. In the past 25 years for example, tropical reef fish have suffered severe outbreaks of *Brooklynella*, a marine disease caused by a protozoan, or single-celled animal, that infects reef fish under stress. Massive die-offs of sponges and blooms of cyanobacteria, which can produce biological toxins, have also been documented during extended periods of elevated sea-surface temperatures. Shellfish diseases like *Vibrio vulnificus* are more virulent in warmer water temperatures.
- **Hypoxia:** Warm water holds less dissolved oxygen than cold water. *Hypoxia*, or low oxygen, occurs when the levels of oxygen dissolved in water fall below levels necessary to support ocean and coastal life, and can lead to what is called a “dead zone.” Nutrients can cause or exacerbate hypoxic conditions by causing certain organisms to proliferate, leading to decreased oxygen when they decay.
- **Changes in the distribution of native and exotic species:** As marine species shift northward with overall warmer ocean temperatures, this shift may have either negative or positive impacts. Some species may be able to survive farther north than in current ranges, but interactions among communities with new species compositions cannot be predicted. Moreover, reproduction in some fishes decreases in warmer temperatures, potentially resulting in population decreases.
- **Changes in nutrient supply, recycling, and food webs:** The metabolism of marine and coastal ecosystems is affected by water temperature, nutrient supply, and volume of freshwater inputs. How efficiently or inefficiently nutrients move through the food web can affect the diversity, number, and economic value of living marine resources.

Scientific American article, “Climate Change Shifts Range and Behavior of Ocean Species,” by Elizabeth Harball and ClimateWire. Aug 6, 2013. <http://www.scientificamerican.com/article.cfm?id=climate-change-shifts-range-and-behavior-of-ocean-species>

Image source: Photographs by Ryan Moyer. A: Healthy coral reef and good water quality

B: Degraded and dying coral reef and poor water quality

4. Increasing Sea Level

- The rate at which sea level increases is as important as the amount it increases.
- Effects:
 - Increased stresses to plants and animals
 - Changes in landforms
 - Loss of tidal wetlands, tidal rivers, and estuaries
 - Increased instability of beaches, barrier islands, and inlets
 - Increased threats to Florida's freshwater supplies



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Geological studies of Florida show that throughout history sea levels rose and fell very rapidly, and then in more recent times began to slow. For the past few thousand years, the sea level around Florida has been rising at a slow pace. Now, in recent decades, a significant and alarming rate of increase in sea level rise has caused some concern.

Effects:

- **Changes in estuaries, tidal wetlands, and tidal rivers:** Although Florida tide ranges are relatively small, tidal effects extend far inland because much of the state is so low and flat. Because sea level has been relatively constant for a long time, tidal wetlands such as mangrove forests and salt marshes have been able to grow into expansive habitats for estuarine and marine life. However, these tidal wetlands are sensitive to the rate of sea-level rise and can perish if sea-level rise exceeds their capacity to adapt. Major redistributions of mainland and barrier island sediments may have compensatory or larger benefits for wetland, seagrass, or fish and wildlife communities, but these processes cannot be forecast with existing models.
- **Changes in beaches, barrier islands, and inlets:** Beaches and inlets are regional systems of sediment deposition, erosion, and transport. These processes are profoundly affected by changes in sea level and rates of sea-level change, as well as storm events.
- **Reduced coastal water supplies:** Sea levels in Florida are expected to eventually rise to the degree that saltwater intrusion will threaten the aquifers that currently supply much of Florida's drinking water in low-lying areas. This problem will be exacerbated by increased withdrawals of water for the anticipated increase in Florida's population.
- **Changes in the ability of stormwater to drain:** Many stormwater systems were designed and constructed decades ago. As sea levels have risen, the gradient between the land and sea surface has lessened, making it more difficult for stormwater to drain. At extreme high tides, seawater now floods parking lots through stormwater pipes in some locations.

What Will Florida Need to Do?

- Accept the consequences and seek to prepare ourselves
- Mitigate the effects by
 - Minimizing harmful actions to the environment
 - Preserving what we can
 - Develop renewable energy sources
 - Reduce carbon dioxide emissions
 - Increase water reuse and rainwater harvesting



What Will Florida Need to Do?

- Adapt
 - Create natural buffers against sea-level rise
 - Develop heat-health action plans
 - Relocate or raise coastal infrastructure (roads, hospitals, water treatment plants)
 - Redesign stormwater drainage systems



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Differences between mitigation and adaptation:

- Through *mitigation* we can stop or minimize the potential negative impacts of climate change.
- Through *adaptation* we are simply adjusting to the impacts of climate change without addressing the causes of climate change. Adapting means that we may have to change our way of life, infrastructure, and/or economy.

The National Academy of Sciences reports that it will take an 80% reduction in emissions just to stabilize atmospheric CO₂ at current levels.

Need to advocate for government policy changes.

- Renewable energy standards
- Energy efficiency standards

Making Choices in the Face of Risk

- The cost of inaction will be far greater than the cost of taking action
 - The cost of inaction will increase from \$27 billion (by 2025) to \$354 billion (by 2100)
- The results of inaction may be irreversible



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Establishing a strong scientific knowledge base and analysis of the situation is of utmost importance in taking necessary actions. Uncertainty is not a reason for inaction. There are a lot of things we already know and we can predict the consequences of those things.

Reasons for taking action:

- The sooner serious efforts to reduce greenhouse gas emissions proceed, the lower the risks posed by climate change
- Getting the relevant incentives and policies set forth now will provide crucial guidance for decisions that will help reduce greenhouse gases
- The actions taken to reduce vulnerability will also double as protection against natural climate variations and extreme events

Because nearly every aspect of our daily living results in carbon emissions, the response must engage every sector of society.

Making Choices in the Face of Risk

“...we have at most 10 years—not 10 years to decide upon action, but 10 years to alter fundamentally the trajectory of global greenhouse emissions.

There is still time, but just barely.”

— Dr. James Hansen
NASA Goddard Institute for Space Studies



Climate Change Consequences for Florida

- Infrastructure
 - Water, power, telecommunication, transportation and buildings
 - Designed based on past environmental criteria



Consequences can include impacts to essential infrastructure (buildings, roads, and freshwater supplies)...

Climate Change Consequences for Florida

- Human Health
 - Storm water discharges carry nutrients, toxins, and fecal contaminants from the land into coastal waterways
 - Fertilizer runoff increases with storms



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...to impacts to the health of residents and visitors, to the preservation of natural systems, economic well-being and long-term stability...

- Storm water discharges carry nutrients, toxins, and fecal contaminants from the land into coastal waterways.
- Fertilizer runoff increases with storms.
- Increased frequency, intensity, and duration of harmful algal blooms; the emergence of previously unknown toxic algae; an increase in water-borne (cholera) and mosquito-borne diseases (malaria), etc.
- Threats to biodiversity: invasives, diseases, range shifts, habitat degradation

Climate Change Consequences for Florida

- Economic Impacts
 - "...negative impacts will outweigh benefits for most sectors that provide goods and services. The impacts will place immense strain on public sector budgets. The secondary impacts of climate change can include higher prices, reduced incomes, and job losses."



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...to economic well-being and long-term stability.


Quote source: Center for Integrative Environmental Research (CIER) and the University of Maryland. *The US Economic Impacts of Climate Change and the Costs of Inaction*. October 2007.


<http://cier.umd.edu/documents/US%20Economic%20Impacts%20of%20Climate%20Change%20and%20the%20Costs%20of%20Inaction.pdf>

Long-Term Solution

- In order to minimize the adverse consequences of our actions, we need to make it a priority to reduce the amount of greenhouse gases and carbon dioxide entering the atmosphere.





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In order to improve levels of certainty about how climate change may impact Florida, we need to analyze models and maps at the appropriate scale so we can address the relevant changes that need to take place.

What are our governments doing? (Add info for your county.)

Example: Monroe County

- Helped create GLEE (Green Living and Energy Education) ('05 +) and conducted the first GLEE Expo
- Signed US Mayors' Agreement on Climate Change ('07)
- Greenhouse Gas Inventory for County Operations ('08)
- Southeast Florida Regional Climate Compact ('09)
- Monroe County Climate Action Plan (2013)

What is the community doing?

- Lifestyle changes are necessary
- Use public transportation, walk or cycle
- Recycle
- Increase your energy efficiency
- Adopt renewable energy when possible
- **ADVOCATE!**

The Florida Oceans and Coastal Council (2005)

Priorities are to establish a statewide agenda that

- Prioritizes ocean and coastal research
- Identifies where the funding is most needed
- Coordinates public and private research for more effective coastal management



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The Florida Oceans and Coastal Council was created by the 2005 Legislature through The Oceans and Coastal Resources Act (http://www.floridaoceanscouncil.org/meetings/files/Oceans_Council_Act.pdf)

Appointing agencies:

- Department of Environmental Protection
- Florida Fish and Wildlife Conservation Commission
- Florida Department of Agriculture and Consumer Services

<http://www.floridaoceanscouncil.org/>

Sample County Climate Action Plan: Top Recommendations

- Action P-2.1: **Revise County Comprehensive Plan** to address strategic planning related to climate change mitigation and adaptation needs.
- Action P-1.1: Develop an **implementation strategy** for the County Community Climate Action Plan.
- Action P-2.3: Create policies for future development to **incorporate sea level rise inundation vulnerabilities** for the life expectancy of the infrastructure.



Monroe County example. The full document can be found at: <http://www.monroecounty-fl.gov/documentcenter/view/5971>

Top Recommendations, *cont'd*

- Action M-2.2: Use improved inundation mapping to **identify the sections of roadways, critical structures and natural areas** that will be affected by sea level rise projections.
- Action P-1.3: Provide **advocacy and leadership** for adoption of climate change policies and legislation with local, state, and federal entities.
- Action P-2.4: Incorporate "**Adaptation Action Area**" designation into local comprehensive plans and regional planning documents to identify those areas deemed most vulnerable to sea level rise and other climate change impacts.



The full document can be found at: <http://www.monroecounty-fl.gov/documentcenter/view/5971>

Circle Questions

- Based on what you have learned so far, what are the most important factors driving climate change?
- What do you think the most significant impact will be to your community?
- What does it mean for our communities to adapt?
- Is it ethical to try to interfere with sea level rise and climate change or should we just let nature run its course?
- What are some of the ways we can educate the community about living a more sustainable lifestyle and reducing their carbon footprint?



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Think about which of the consequences of climate change are likely to have the greatest impact to the economy and our resources?

What can we do to mitigate these changes or adapt?

Distinguish between *adaptation* and *mitigation*.




If time allows...

What are "trusted sources of information"? Do you trust the news media? Why or why not?

What agendas could be driving information provided by various sources?

Take Home Message

- Future generations will have to face the consequences of our current and past actions.
- The long-term extent and severity of effects caused by climate change ultimately depend on how rapidly we can control human sources of carbon dioxide and other greenhouse gases entering the atmosphere.
- What are some of the key concepts from this module that you would like to share with others?



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Final notes

In the face of a changing environment, long range planning that considers the principles of adaptive management and uses foresight is a good first step.

According to the USGS:

Adaptive management has been described variously as “learning by doing, and adapting based on what's learned,” “management in the face of uncertainty, with a focus on the reduction of that uncertainty,” and “management that recognizes uncertainty in its consequences and seeks to improve understanding so as to improve decision making.” Whatever the description, adaptive management is seen as a systematic approach for improving natural resource management, with an emphasis on learning about management outcomes and incorporating what is learned into ongoing management.

Who is going to be the whistle blower? We need someone to take the lead and start advocating to the community.

Revisit Learning Goals to make sure they were met:

- to advance environmental literacy and civic engagement in environmental issues
- to understand the significance of climate change and sea level rise and the consequences we may have to face as a result.
- to understand which drivers are having the most detrimental environmental impacts
- to gain insight to what is being done to mitigate and adapt to our dynamic environment

Hope you enjoyed the course!



Any Questions?



Image source: Photographs by Rhonda Haag