HURRICANE RESILIENCE

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Through 20 days of instruction, students make connections between the science of hurricanes, how they affect their community and region, and how we can plan for a more resilient future. Making local connections, students develop an understanding of the risks that their local community is facing now and in the future due to hurricanes and tropical storms, how sea level rise increases the risk, and how our actions can help us be less vulnerable and more resilient.

The curriculum unit aims to empower high school students to have a voice in resilience planning and help them understand the relationship between the science of hurricanes and the local impacts of these storms on people and places.

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About the Curriculum

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Lesson Outline

	Lesson Number	Lesson Title	Lesson Questions	Class Periods
PART 1 HURRICANES AFFECT US	1	Hurricane Headlines	What do people do when a hurricane is approaching and how are people affected when a hurricane hits?	1
	2	Historical Hurricanes	Which hurricanes and tropical storms have affected our community?	2
	3	Storm Stories	How have people in our community experienced hurricanes?	4
PART 2 HURRICANE CHARACTERISTICS AND FUTURE PROJECTIONS	4	No Two Storms Are the Same	Which aspects of hurricanes and tropical storms are most hazardous?	2
	5	Hurricanes and Climate Change	Is warming affecting hurricanes?	1
	6	Sea Level Rise	How will sea level rise affect our coast in the future?	1
	7	Warmed-up Storms	What would past hurricanes be like if they happened in a warmer world?	1
PART 3 PLANNING FOR HURRICANE RESILIENCE	8	Modeling Hurricane Impacts	How can we modify our model communities to be less affected by storm surge flooding?	1
	9	Assessing Vulnerability & Risk	What parts of our community are most vulnerable and most at risk?	1
	10	Short and Long Term Resilience Planning	What actions can we take to decrease hurricane risk and vulnerability in the short term and in the long term?	2
	11	Communicating Resilient Actions	What do we tell other people in our community about how we can be more resilient?	4

Overview

Suggested Calendar

Monday	Tuesday	Wednesday	Thursday	Friday
Lesson 1 Hurricane Headlines	**Lesson 2** Historical Hurricanes	**Lesson 2** Historical Hurricanes	**Lesson 3** Storm Stories (planning)	**Lesson 3 *** Storm Stories (interview training)
Lesson 3 Storm Stories (data analysis)	**Lesson 3** Storm Stories (data analysis)	**Lesson 4** No Two Storms Are the Same	**Lesson 4** No Two Storms Are the Same	**Lesson 5** Hurricanes and Climate Change
Lesson 6 Sea Level Rise	**Lesson 7** Warmed-up Storms	**Lesson 8** Modeling Hurricane Impacts	**Lesson 9** Assessing Vulnerability and Risk	**Lesson 10** Short and Long Term Resilience Planning
Lesson 10 Short and Long Term Resilience Planning	**Lesson 11** Communicating Resilient Actions (introduction)	**Lesson 11** Communicating Resilient Actions (planning)	**Lesson 11** Communicating Resilient Actions (creating)	**Lesson 11** Communicating Resilient Actions (presenting)

** Students conduct a Storm Stories interview during the first weekend of the unit and then analyze the data as a class the following Monday and Tuesday.*

Skills that students utilize

Geography and Sense of Place: Throughout the curriculum, students connect with their location through research about which historical hurricanes have affected their location, interviews to document storm damage, mapped data about winds, rain, and flooding associated with hurricanes, and resilience planning for their local area. Additionally, an optional Arc-GIS component can be added to Lesson 3, which allows students to map their interview data.

Engaging in an Argument from Evidence: At several points in the curriculum, students need to make a claim and then support their claim by describing evidence and explaining their reasoning.

Interviewing: Students interview people from their community to collect qualitative data about local experiences with hurricanes (Lesson 3).

Analyzing and Interpreting Data: Students analyze qualitative data such as news headlines (Lesson 1) and interview results (Lesson 3). They analyze quantitative data about hurricane tracks (Lesson 2), storm characteristics (Lessons 4), and how hurricanes have changed over time (Lesson 5).

Developing and Using Models: Students model sea level rise in a warmer world using NOAA Digital Coast (Lesson 6) and then analyze model data showing hurricanes in a warmer world (Lesson 7). Also, students create a physical model of a hurricane making landfall and test it (Lesson 8).

Designing Solutions: Students developed a more resilient infrastructure for their coastal models that they test with a simulated hurricane (Lesson 8). Related to their local setting, they develop and describe resilience actions based on their research (Lessons 10-11).

Obtaining, Evaluating, and Communicating Information: While students are using these skills throughout the curriculum, there is a strong focus on these skills in Part 3. In Part 3, students gather information about resilience strategies (Lessons 10) and then use communication skills to share what they have learned about dangerous aspects of hurricanes and strategies that they recommend to help people be resilient (Lesson 11).

Standards Addressed

NGSS Performance Expectations

- HS-ESS3-1. Construct an explanation based on evidence for how the ~~availability of natural resources~~, occurrence of natural hazards, and changes in climate have influenced human activity.
- HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. (Lessons 6-7)
- HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. (Lesson 7)
- HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. (Lessons 9-11)

Common Core English Language Arts

Lesson 12 addresses:

- CCSS.ELA-LITERACY.SL.9-10.4. Present information, findings, and supporting evidence...
- CCSS.ELA-LITERACY.SL.9-10.5. Make strategic use of digital media...
- CCSS.ELA-LITERACY.SL.11-12.4. Present information, findings, and supporting evidence...
- CCSS.ELA-LITERACY.SL.11-12.5 Make strategic use of digital media...

National Geography Standards

- Standard 1: How to use maps and other geographic representations...
- Standard 4: The physical and human characteristics of places
- Standard 14: How human actions modify the physical environment
- Standard 15: How physical systems affect human systems
- Standard 18: How to apply geography to interpret the present and plan for the future

Students at South Terrebonne High School creating a model coastline to test with a simulated hurricane during Lesson 8 of the Hurricane Resilience curriculum (Lisa S. Gardiner)

Using a Driving Question Board

Throughout the Hurricane Resilience curriculum, students use a Driving Question Board to document their questions about hurricanes and tropical storms, the damage they cause, and how to stay safe.

A Driving Question Board is a tool to generate, keep track of, and revisit student questions related to the phenomena that the class is exploring, which, in this curriculum, are hurricanes and related topics that impact coastal resilience. The Driving Question Board is introduced at the beginning of the unit and then revisited periodically as students develop additional understanding of the phenomena. It is important that students understand there will be more questions on the Driving Question Board than can be answered during the unit.

The Driving Question Board is a visual representation of the questions and should be displayed in the classroom throughout the unit. A Driving Question Board can be constructed with sticky notes or sentence strips, written on whiteboards, or made with shared software applications.

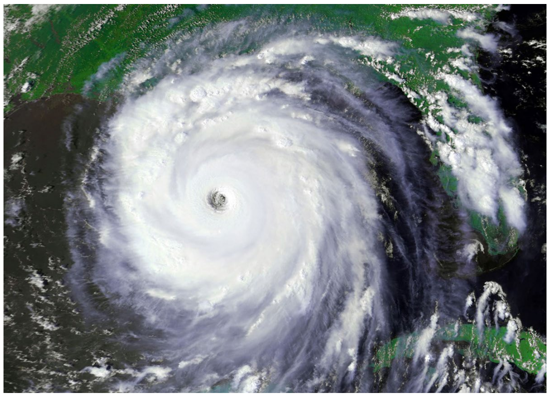
To prepare the Driving Question Board for your class:

- Write a question on a sheet of poster board or chart paper. While there is a question associated with each lesson, the driving question at the center of the Driving Question Board should be more general, for example: *How and why do hurricanes affect us and how can we stay safe?*

Overview

- Display the Driving Question Board so that it is easily accessible to students - either in the classroom or a virtual, online location that students can access. Students will revisit the board periodically during the unit. Depending on your class, you may wish to have students revisit the board more often than suggested in lessons.
- Provide sticky notes and markers for students to document their questions if using a classroom Driving Question Board.

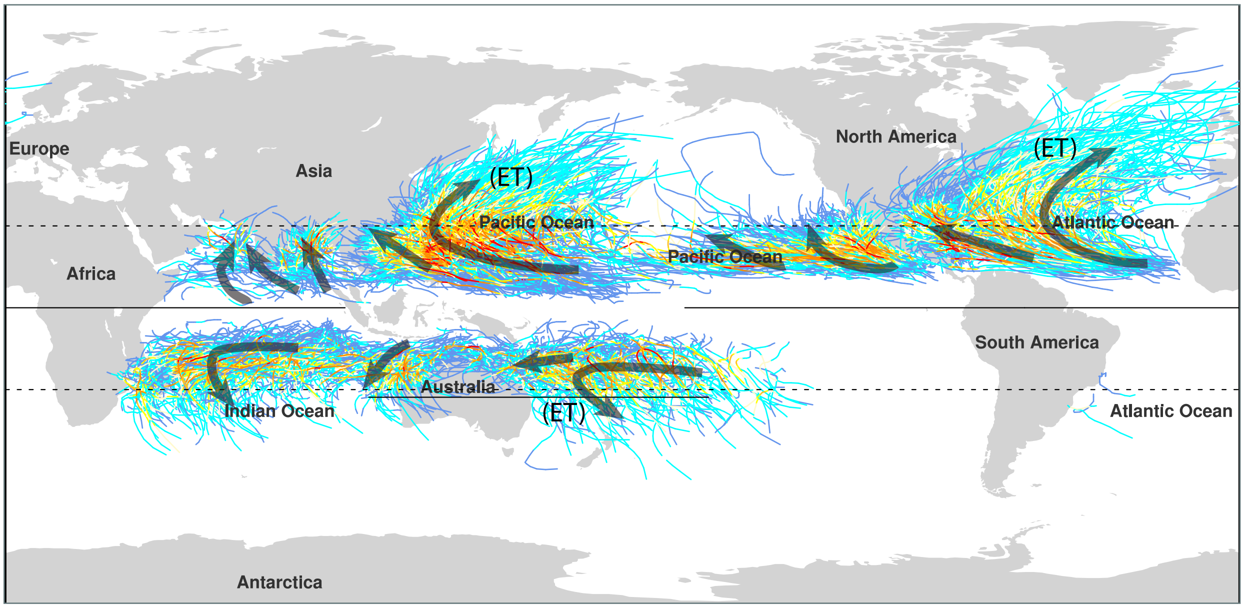
Background Science



A satellite image of Hurricane Katrina approaching the U.S. Gulf Coast in 2005. (NOAA)

About hurricanes and tropical storms:
Hurricanes and tropical storms, known more generally as tropical cyclones, are weather systems that form in the tropics (typically 30° North and South of the equator) and generate winds greater than 63 km/h (39 mph) that rotate counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. When these storms have sustained winds exceeding 119 km/h (74 mph), they are known as hurricanes over the North Atlantic and Central and East Pacific oceans, and are called typhoons over the western North Pacific Ocean. Over the Indian Ocean and the South Pacific, they are called cyclones. These storms mainly occur during the summer season (which is at opposite times of the year in the Northern and Southern Hemispheres).

Where do hurricanes form and travel?
Similar to a stick floating down a stream, the route, or track, of a hurricane is largely controlled by the prevailing winds, which, at tropical latitudes (<30°) typically flow from East to West and are called Trade Winds. At higher latitudes, the prevailing winds flow from West to East.



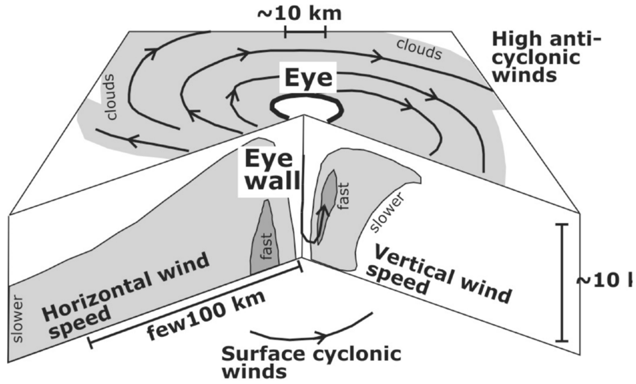
Credit: Ming Ge (NCAR), published in Done and Owens (2017).

The world map above shows the tracks of hurricanes and tropical storms between 1980 and 2013 colored by the Saffir-Simpson category. Arrows indicate general tracks, and '(ET)' indicates where these storms can transition to become extratropical storms (i.e., outside the tropics). Notice on the map that they occur only rarely over the South Atlantic and the eastern South Pacific. Hurricanes and tropical storms are most prevalent from June to November in the Northern Hemisphere peaking in mid-September, and from November to April in the Southern Hemisphere peaking in mid-February.

Anatomy of a hurricane

Mature hurricanes are approximately symmetrical about a central eye. The eye is a calm area surrounded by a wall of strong winds and rain known as the eyewall.

The illustration to the right shows the basic structure of a hurricane and the terms used for its different parts. Horizontal winds spiral cyclonically inwards, and are fastest just above the ground or ocean surface and in the eye-wall where vertical winds send air high into the upper troposphere and lower stratosphere. This upward moving air fans out anti-cyclonically at the top of the storm, which means that the winds at the top of the storm are rotating opposite to the winds at the bottom of the storm. In the Northern Hemisphere, cyclonic is anticlockwise, and anticyclonic is clockwise (note the wind directions in the diagram above). Winds rotate in the reverse pattern in hurricanes and tropical storms in the Southern Hemisphere.



Credit: Done and Owens (2017) adapted from Kerry Emanuel (2003)

How do hurricanes form and grow?

Typically, hurricanes and tropical storms transfer heat energy from the tropical ocean surface, where sea surface temperatures (SSTs) are more than 26° C, into the atmosphere. This process is called cyclogenesis. Several other factors must also align for these storms to form, including:

- Warm, moist air with a tendency to rise, is essential. The rising air moves heat energy higher in the atmosphere and establishes the storm's structure.
- Humid conditions at mid-levels are needed to limit downdrafts of dry air.
- Wind shear must be low. Wind shear is the difference between winds at low and high altitudes. When strong, it can tear apart a developing tropical storm.
- Finally, a trigger is needed to start a storm. Triggers can be various types of atmospheric phenomena, including trailing cold fronts, monsoonal circulations, or pulses of energy in the atmosphere known as tropical waves.

For more information: NOAA SciJinks: How Does a Hurricane Form? (scijinks.gov/hurricane/)

How do we know which tropical cyclones are most dangerous?

The Saffir Simpson Scale is used to describe hurricanes, tropical storms, and tropical depressions based on wind speeds. Tropical storms have winds greater than 39 mph and less than 74 mph. When these storms have sustained winds of more than 74 mph, they are called hurricanes in the North Atlantic.

As hurricanes grow stronger, wind speeds increase, and so does the hurricane category. However, the most dangerous storms are not necessarily the strongest at landfall. Low category hurricanes and tropical storms have caused significant damage due to flooding. Although hurricanes are categorized into the Saffir-Simpson scale according to their wind speeds, most fatalities associated with hurricanes are caused by flood water, not wind.

Researchers at the National Center for Atmospheric Research, including Dr. James Done, are developing other types of hurricane scales to have different ways to indicate the type of storm that is heading towards a coast that better reflects the likely amount of damage. This could help coastal residents understand whether an approaching storm is likely to produce lots of rain or storm surge flooding, regardless of the wind speeds.

Saffir-Simpson Scale

Name	Wind Speed
Category 5 Hurricane	*> 155 mph*
Category 4 Hurricane	*131-155 mph*
Category 3 Hurricane	*111-130 mph*
Category 2 Hurricane	*96-110 mph*
Category 1 Hurricane	*74-95 mph*
Tropical Storm	*39-73 mph*
Tropical Depression	*< 39 mph*

Overview

Hurricanes and tropical storms can have very different characteristics.
Some storms are small in scale but bring intense rains. Others have high winds and less rain. The dangerous aspects of a hurricane or tropical storm are not always the same, which is why hurricane categories based only on wind speed may not accurately predict how the storm will affect coastal residents as it makes landfall.

While all hurricanes and tropical storms have similar morphology, they vary in terms of their geographic size, wind speeds, the amount of water vapor they carry, and the speed they move. Below are the characteristics that students analyze in Lesson 4 with definitions.

- **Forward speed:** Hurricanes vary in the speed they travel, which is called translation rate. Slow-moving storms may stall completely while fast-moving storms travel over 500 km (312 miles) in 24 hours.
- **Footprint (geographic scale):** A small storm may have hurricane force winds over an area about 150 km (about 90 mi) across, while a very large storm might have hurricane force winds that affect the coast of several states as the storm makes landfall. A storm with a large footprint has the potential to affect a larger area than a storm with a smaller footprint, but other factors (such as winds and moisture) will determine the types of impacts.
- **Wind speeds:** Historically, wind speeds are used to categorize hurricanes according to the Saffir-Simpson Scale. Once a hurricane or tropical storm makes landfall, winds drop significantly.
- **Rain:** These storms generally carry large amounts of water vapor and clouds, yet some storms carry more water than others. A hurricane or tropical storm with large amounts of water can cause intense rainfall, and the rainfall is not necessarily evenly distributed. Hurricane Harvey, for example, dropped between 30 and 60 inches of rain in the Houston, TX area in 2017. The maps of rainfall data that students explore in Lesson 4 emphasize that the amount of rain can vary with location.
- **Flooding:** The amount of flooding caused by a hurricane or tropical storm relates to factors associated with the storm as well as factors of local geography and the water table. Generally, flooding is due to both rainfall and storm surge (see below).

A note about units: It's common to describe the winds of tropical cyclones in miles per hour and the amount of flooding measured by gauges in feet, which is why units have not been converted to metric.

Madison Canal in Terrebonne Parish, Louisiana, during typical conditions and with storm surge due to Hurricane Barry in 2019. (Left: Adrianna Adams; Right: the Picou family)

How do hurricanes cause flooding?
Flooding is caused by two factors: storm surge and rainfall.

Storm surge: One of the most dangerous hurricane hazards, storm surge, is responsible for about half of all hurricane- and tropical storm-related fatalities. Storm surge happens when strong winds push ocean water towards the coast, causing the water to spill out over the land. The strength of the storm surge depends on the winds, the storm's footprint, forward speed, and the shape of the coast and shallow ocean. Surge is also driven in part by the low surface pressure at the center of the storm, which causes the surge to build up over many days and spill out over the land as the storm makes landfall. Storm surge can inundate coastal locations with many feet of fast-moving water in a matter of minutes.

Rainfall: The amount of rainfall depends on how much moisture a hurricane or tropical storm is carrying and the speed at which a storm is moving. A storm that carries a lot of moisture and is also slow moving can cause a large amount of rain to fall in one location. The rain floods rivers and impervious urban areas. The amount of flooding caused by rain depends on the topography of the land, and whether the water can permeate into the ground.

How many storms happen per year or decade?
The actual number of storms per year or per decade is typically not the same as the average number of storms. Just as your height is likely more or less than the height of an average person, the number of hurricanes and tropical storms during a year is likely more or less than the average number of storms. There is some variability around the average because of environmental changes that vary regionally from year-to-year, such as the temperature of the ocean surface, air temperature, and El Niño.

How does climate change affect hurricanes?
Scientists have determined that the strength and length of storms are probably affected by climate change. There is evidence that the number of hurricanes is increasing due to climate change and is also affected by a natural cycle.

As climate warming causes the ocean surface to warm, the intensity of hurricanes is likely to increase. Hurricanes take heat energy from the oceans and convert it into the energy of the storm. Thus, warmer oceans offer more heat energy to hurricanes, allowing them to become stronger storms with higher winds. Also, as the climate warms, hurricanes are able to transport more moisture, which can cause intense precipitation and devastating floods, like those that occurred with Hurricane Harvey in the Houston, Texas area in 2017.

In Lesson 5, students compare storm data from three time periods to explore whether there is a trend in the number of strong hurricanes. Students observe that there is evidence that storms are becoming stronger and also note that the number of storms may be increasing, but the trend isn't as clear in all regions. There is strong evidence that recent climate change caused by humans has been increasing the intensity of hurricanes.

The impact of climate change on hurricanes and tropical storms is an area of active research. We do know that a warmer climate causes these storms to carry more moisture and produce more rain. We also know that a warmer climate is causing warmer sea surface temperatures, which make a hurricane's winds stronger. There are regional variations and aspects of storms that scientists are still investigating, which are described in Lesson 7.

Sea level rise is adding to the flood risk posed by hurricanes.
To understand how hurricanes and tropical storms will affect their coastal location in the future, students take into account the impacts of sea level rise in Lesson 6.

Climate change is causing global sea level to rise in two ways.

- First, when climate warms, glaciers and ice sheets melt and the meltwater makes its way down rivers to the ocean. This moves water that had been on land into the ocean. With more water in the ocean, sea level rises.
- Second, as seawater warms, the water molecules move further apart. This causes the water to expand. About half of the sea level rise that is happening today is due to the expansion of water as it warms.

Sea level along a coast is also affected by sinking and uplifting of the land. This effect is regional. For example, coastal Louisiana is sinking lower each year, a process called subsidence. Because the land is sinking, the sea level appears to be rising much faster than if the land was stable and the only impact was from global sea level rise caused by climate change. The opposite occurs as well if the land is uplifting. For example, in areas of coastal Alaska, sea level appears to be falling because the land is uplifting rapidly due to plate tectonics.

What is resilience?

Resilience is the ability to bounce back or recover from difficulties. There are multiple ways to plan for resilience. For example, one could reduce vulnerability to flood water by raising a house on stilts. Another way to plan for resilience is to design for "graceful failure," which is to ensure that negative consequences are not dire when adversely affected by a hazard. For example, by designing a house with a ground floor made from materials that can be flooded without harm, negative consequences of flooding are prevented.

In order to plan for resilience, it's important to first understand what is at risk. In Part 3 of the curriculum, students determine what aspects of their community are **vulnerable** and then calculate the relative **risk** based on the vulnerability. Below are definitions of these terms and examples.

- **Vulnerability** is a combination of several factors, including whether something is exposed to a hazard, whether it is sensitive to the hazard, and whether it is adaptable. For example, a home located on an exposed, hurricane-prone coast is in harm's way. If that house is a small wooden structure built on sand, then it is very sensitive to the winds and flooding associated with a hurricane. However, if it has the capacity to be adapted - for example, by being moved to a more stable location and on a raised foundation - then this can decrease its vulnerability.
- **Risk** is based on the vulnerability combined with the consequences if the item or place were destroyed. For example, if our very vulnerable house was an unoccupied shack, then no one would become homeless if it were destroyed by a landfalling hurricane. But if the house was home to people, and if it was one of 40 similar houses that made up a small coastal community, then the consequences would be larger. Forty households of people could become homeless if the houses were destroyed by a landfalling hurricane, thus the risk would be higher.

The U.S. Climate Resilience Toolkit outlines five steps to being more resilient (toolkit.climate.gov/#steps). While the toolkit is used to make steps towards resilience at large scales - such as an entire state or city - the same strategies are helpful at a smaller scale, too - such as for an individual household.

1. Explore Hazards
2. Assess Vulnerability & Risks
3. Investigate Options
4. Prioritize & Plan
5. Take Action

The table to the right outlines which steps of the *Climate Resilience Toolkit* align with the lessons in Part 3 of the *Hurricane Resilience* curriculum. The Toolkit website (toolkit.climate.gov) includes information and helpful videos that explain each step, which you may wish to add to these lessons to further support student learning.

	Correlating Parts of The Resilience Toolkit
Lesson 9	**Step 1: Explore Hazards** • List the things you value that could be damaged. **Step 2: Assess Vulnerability & Risks** • Determine which of your assets are exposed to harm. • Assess each asset's vulnerability. • Estimate the risk to each asset.
Lesson 10	**Step 3: Investigate Options** • Consider possible solutions for the highest risks. • Check how others have responded to similar issues. • Reduce your list to feasible actions. **Step 4: Prioritize & Plan** • Rank the expected value of each action.
Lesson 11	**Step 4: Prioritize & Plan** • Evaluate costs, benefits, and challenges. **Step 5: Take Action** • In this case, students' actions are to develop communications materials to help others understand what they can do to improve resilience.

Case study: Louisiana resilience planning

LA SAFE stands for Louisiana's Strategic Adaptations for Future Environments. In the Lesson 11 case study, students assess information from the LA SAFE Terrebonne Parish adaptation plan developed in 2018. The goals of the LA SAFE planning process are to:

- To generate parish-wide community-driven adaptation plans focused on opportunities for residents and stakeholders to proactively adapt and prepare for anticipated environmental changes over the next 10, 25, and 50 years.
- To implement a catalytic project in each of the six parishes that demonstrates adaptive development practices that conform to current and future flood risks. Furthermore, LA SAFE is intended to identify and support the development of resilience-building projects and practices that can serve as models for the entire region.
- To create a statewide adaptation model that enhances long-term sustainability and resiliency for all Louisiana parishes.

Natural wetlands in south Louisiana help buffer the coast as hurricanes approach. (Lisa S. Gardiner)

Because natural wetlands are disappearing as sea level rises, engineered wetlands are being developed in coastal Louisiana to help buffer the coast. (Lisa S. Gardiner)

Planning for living with hurricanes in the short- and long-term

In the *Hurricane Resilience* curriculum, students consider two types of resilience strategies: (1) short-term planning for safety when a hurricane is heading for the coast, and (2) long-term planning that can help decrease vulnerability and risk overall, making people better able to weather storms. These categories have some overlap so students may identify actions that fit into both (for example, planning evacuation routes could be for a particular storm or could be a part of long-term planning to consider how to reduce traffic congestion during evacuations in a region).

In addition, students also divide resilience actions into those that can be accomplished by an individual or household and those that need the support of an entire community or region. For example, for long-term planning, raising a home above the level of extreme flooding is something a household can do while adding a levee around an area of the coast would be a project for a community or several communities in a larger area.

Actions for hurricane resilience in the short-term

Once the hazards posed by hurricanes and tropical storms are known and understood, people can decrease their risk with actions such as:

- Creating household and school/workplace emergency plans that address people's needs and include how to support people with disabilities.
- Developing a hurricane disaster supply kit that includes essentials. (See *ready.gov/kit* for items to include.)
- Making an evacuation plan. Plan your route and where you'll stay.
- Paying attention to hurricane forecasts and warnings.
- Securing homes, businesses, yards, and vehicles
- Procuring supplies
- Evacuating

Long-term resilience planning for hurricanes and sea level rise

Making plans and taking actions for resilience at a coastal, hurricane-prone location can help individuals, households, and communities decrease the risk and vulnerability they face now and in the future. Examples of actions that promote resilience in the long-term include:

- Buying flood insurance
- Raising homes on stilts
- Moving wiring higher on walls to be above flood level
- Replacing roofing with wind-proof materials
- Moving to higher ground
- Replacing impervious surfaces like asphalt with pervious pavement, which allows water to drain
- Building a levee to protect a community or region
- Creating a buyout program to help residents in the most vulnerable locations move to safer areas
- Restoring wetlands, which buffer the coast during a hurricane

References:

Done, J. M. and B. Owens Chapter 7.3 Tropical Cyclones. In Mitchell-Wallace, K., Jones, M., Hillier, J. and Foote, M. (Eds) 2017. Natural catastrophe risk management and modeling: A practitioner's guide. John Wiley & Sons.

Emanuel, K., 2003. Tropical cyclones. Annual review of earth and planetary sciences, 31(1), pp.75-104.