Today I Learned About Hurricanes

Description:

Hurricanes are a fact of life for millions of Americans each year, and billions more people around the world. What is a hurricane, and how can we prepare for them? Through a model and student-level data, students explore the factors influencing storm frequency and intensity. They also consider the language of storms, as well as steps to resilience.

Skills & Objectives

SWBAT

- Explain that hurricanes are influenced by sea surface temperatures, moisture, wind, and other factors.
- Understand that increased heat in the atmosphere, ocean, and land are changing the frequency and intensity of hurricanes.
- Name a few concepts for hurricane resilience.

Skills

- Modeling
- Graphing
- Discussion

Students Should Already Know That

- Hurricanes are big, dangerous storms that can cause coastal flooding from storm surge, inland flooding from rain, and damage from wind.

Standards Alignment:
HS-ESS2-2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.
HS-ESS3-5 Analyze geoscience data and the results from global climate models.
HS-ETS1-2 Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
RST.11-12.9 Synthesize information from a range of sources into a coherent understanding of a process, phenomenon, or concept.
HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling.

Disciplinary Core Ideas:
ESS2.A Earth Materials and Systems
ESS2.D Weather and Climate
ESS3.D Global Climate Change

TILclimate
Guide for Educators

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How To Use These Activities:

Pages with the circular "TILclimate Guide for Educators" logo and dark band across the top are intended for educators. Simpler pages without the dark band across the top are meant for students.

Each of the included activities is designed to be used as a standalone, in sequence, or integrated within other curriculum needs. A detailed table of contents, on the next page, explains what students will do in each activity.

A Note About Printing

All student pages are designed to be printable in grayscale.

The worksheets do not leave space for students to answer questions. Students may answer these questions in whatever form is the norm for your classroom – a notebook, online form, or something else. This allows you, the teacher, to define what you consider a complete answer.

A Note About Data

The data on pages 5, 6, and 7 is available for download at https://climate.mit.edu/ed/hurricanedata

Extension Activity

For groups with the time and resources, the role-playing activity "Coastal Flooding and Climate-Related Risks in Launton" (2-3hr, $3 per participant) leads participants through a negotiation among stakeholders in a small beachfront community.

https://www.pon.harvard.edu/shop/coastal-flooding-and-climate-related-risks-in-launton/

Podcasts in the Classroom: Throughout these Guides for Educators, we invite students to think about how they would share their learning with family and friends. One way to do this is to encourage your students to create their own podcasts - they're shareable, creative, and have multiple options for embedded assessment. We would love to hear any podcasts or see any other projects you or your students create! Email us at tilclimate@mit.edu, Tweet us @tilclimate, or tag us on Facebook @climateMIT.

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Detailed Table of Contents

Social-Emotional Learning

All climate change topics have the potential to be overwhelming or scary for students. Students whose lives or family members have been threatened or disrupted by hurricanes may find this topic more difficult to discuss than others. The activities in this Guide do not focus on any particular storm, nor do they focus on traumatic impacts.

For more information on trauma-informed climate education, see pages 6&7 "How to Use TILclimate Educator Guides" (included with this guide or accessible from https://climate.mit.edu/til-about-hurricanes-educator%20guide)

Today I Learned About Hurricanes

Hurricanes and Resilience

This Educator Guide includes a model, articles, and student-level data. Educators may pick and choose among the pieces of the Guide, as suits their class needs.

Parts of this Guide may align with the following topics:

- Physical science: The physics of hurricanes, the physics of wind-resistant construction
- Life/environmental science: Coral reefs as hurricane "speedbumps," wetlands ecosystem services
- History/social science: History of hurricane naming and terminology, impact of hurricanes on human migration and policy.
- ELA/literature: Connections to stories about hurricanes
- ELA/nonfiction: Communicating complex scientific and resilience concepts
- Mathematics: Statistical modeling from real-world data

MIT Resources

We recommend the following as resources for your own better understanding of climate change or as depth for student investigations. Specific sections are listed below:

- Climate Science, Risk & Solutions, an interactive introduction to the basics of climate change. https://climateprimer.mit.edu/
  - Chapter 02 The greenhouse effect and us
  - Chapter 06 Predicting climate
  - Chapter 07 Understanding risk
  - Chapter 08 What are the risks?
  - Chapter 10 What can we do?
- MIT Climate Portal Explainers are one-page articles describing a variety of climate topics. New Explainers posted monthly. https://climate.mit.edu/explainers
  - Climate-Resilient Infrastructure
  - Sea Level Rise
  - Coastal Ecosystems and Climate Change
  - Cities and Climate Change
  - Hurricanes
  - Climate Models
  - Greenhouse Gases

Today I Learned About Hurricanes

Wrap-Up Discussion Questions

- How do warming ocean and air temperatures affect hurricane formation?
- What are some challenges that might arise from using different words for the same type of storm? (Consider multi-national corporations or international aid organizations.)
- What are some challenges that might arise from using human names for storms, especially across areas that include many countries?
- Given the patterns that you identified in the historical data, what would you expect the next decade's hurricane seasons to look like?
- What other questions do you have about hurricanes? Where might you look for that information?
- Which resilience solutions did you like the best? Why? How do they help a community be resilient to hurricanes?

Climate Solutions

Climate solutions can be thought of as falling into four categories outlined below. Across all categories, solutions at the community, state or federal level are generally more impactful than individual actions. For example, policies that increase the nuclear, solar and wind mix in the electric grid are generally more effective at reducing climate pollution than asking homeowners to install solar panels. For more on talking about climate change in the classroom, see "How to Use This Guide".

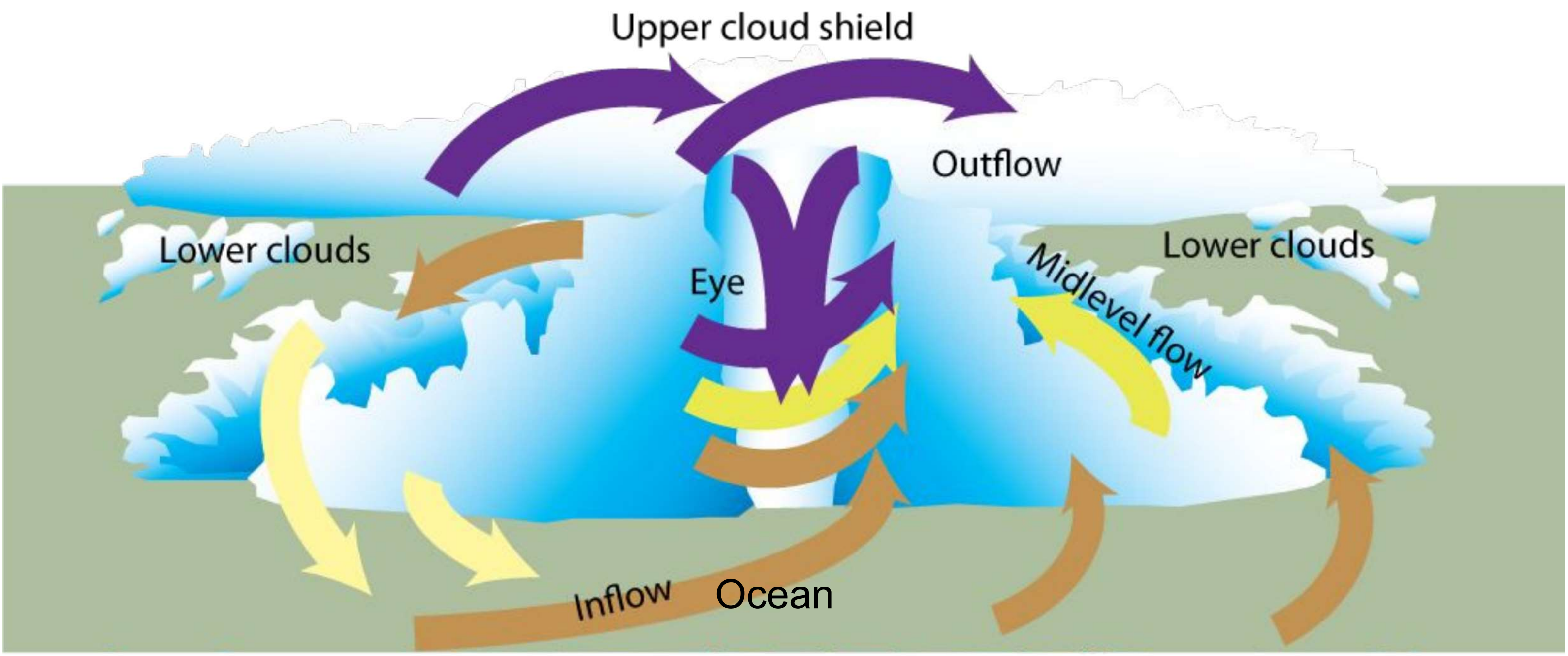
- **Energy Shift**
  How do decision-makers make the switch from carbon-producing energy to carbon-neutral and carbon-negative energy?
- **Energy Efficiency**
  What products and technologies exist to increase energy efficiency, especially in heating and cooling buildings?
- **Adaptation**
  How can cities and towns adapt to the impacts of climate change?
- **Talk About It**
  Talking about climate change with friends and family can feel overwhelming. What is one thing you have learned that you could share to start a conversation?

TILclimate Guide for Educators

What solutions are the most exciting in your classes? We would love to hear from you or your students! Images, video, or audio of student projects or questions are always welcome. Email us at tilclimate@mit.edu, Tweet us @tilclimate, or tag us on Facebook @climateMIT.

Today I Learned About Hurricanes

"Hurricanes are enormous heat engines. They convert heat that they extract from the ocean into wind energy, and the faster they can extract heat from the sea, the more powerful they can become… [T]he wind starts to blow harder over the ocean and that evaporates more water."
Professor Kerry Emanuel, MIT Department of Earth, Atmospheric and Planetary Science
TILclimate podcast: Today I Learned About Hurricanes



Conceptual diagram illustrating how hurricanes are structured and formed.
Diagram courtesy of the Integration and Application Network (ian.umces.edu), University of Maryland Center for Environmental Science. Source: Kruczynski, W.L. and P.J. Fletcher (eds.). 2012. Tropical Connections: South Florida's marine environment. IAN Press, University of Maryland Center for Environmental Science, Cambridge, Maryland. 492 pp.

Model a Hurricane

1. Visit https://scied.ucar.edu/interactive/make-hurricane
2. Move the red hurricane symbol to a circle on the map and read what happens.
3. Switch between the Sea Surface Temperature, Moisture, and Wind maps to see the data for each circle.
4. Which circles create the strongest hurricanes? Why?
5. In your own words, explain how sea surface temperature, moisture, and wind interact to create strong hurricanes – or weaken them.

As we burn fossil fuels like coal, oil, and natural gas and cut down forests, we release carbon dioxide (CO_2) into the atmosphere. This CO_2 acts like a blanket, trapping heat. While we need some blanket to maintain life on Earth, too much CO_2 traps too much heat. This heat is warming our ocean, Earth, and air.

6. How do warming ocean and air temperatures affect hurricane formation?

Graphic courtesy of Kate Bentsen, Integration and Application Network (https://ian.umces.edu/media-library)

MIT ENVIRONMENTAL SOLUTIONS INITIATIVE

Today I Learned About Hurricanes

"[T]he vocabulary is terrible! In the science world everything you know as a hurricane is called a tropical cyclone no matter where it occurs in the world… And tropical storm is also used in this region for tropical cyclones that aren't of hurricane strength. Super storm is not in our vocabulary. That's a … broadcast meteorologist type of thing. It's a very informal thing.

Professor Kerry Emanuel, MIT Department of Earth, Atmospheric and Planetary Science
TILclimate podcast: Today I Learned About Hurricanes

What's in a Word?

In the US, many of us are familiar with the term *tropical storm* and then *hurricanes* in categories 1-5. Depending on where you are in the world, the words for identical storms are different – even when everyone is using the same language. Below are three of the five classification systems recognized by the World Meteorological Organization (WMO.)

Knots	North Atlantic & Northeast Pacific	Southwest Indian Ocean	Northwest Pacific
17	Tropical Depression	Tropical Disturbance	Tropical Depression
28		Tropical Depression	
34	Tropical Storm	Moderate Tropical Storm	Tropical Storm
48		Severe Tropical Storm	Severe Tropical Storm
64	Category 1 Hurricane	Tropical Cyclone	Typhoon
83	Category 2 Hurricane		
90		Intense Tropical Cyclone	
96	Category 3 Hurricane		
113	Category 4 Hurricane (Major Hurricane)	Very Intense Tropical Cyclone	
137	Category 5 Hurricane (Major Hurricane)		

1 knot = 1 nautical mile per hour, 1.150779mph, 1.852km/h

Data from https://public.wmo.int/en/our-mandate/focus-areas/natural-hazards-and-disaster-risk-reduction/tropical-cyclones

Today I Learned About Hurricanes

What's in a Name?

For centuries after European colonization, hurricanes in the Caribbean were named after the Catholic saints' day on which they made landfall. Then, in the late 1800s and early 1900s, they were named for their latitude and longitude. During World War II, US military meteorologists began using first names traditionally associated with women. After the formation of the National Hurricane Center, an alphabetical list of names was developed.

Today, storms in the North Atlantic, Caribbean, and Gulf of Mexico are named from alphabetical lists maintained by the World Meteorological Organization, alternating between names traditionally associated with women and those with men. There are now six lists of 21 names each, which are used in a six-year cycle. (No storm names begin with Q, U, X, Y, or Z.) Names are removed ("retired") from the list if a storm is particularly damaging or deadly.

Before 2021, if more than 21 named storms occurred in a year, the list moved on to the Greek alphabet. This list was used for the first time in 2005. In 2020, a record-breaking storm season required the Greek alphabet again, and the World Meteorological Organization (WMO) decided to change their protocol. Beginning in 2021, there is a supplemental list of 21 names for busy hurricane seasons.

This list is only for storms within the North Atlantic region. The WMO also has lists of names for the other ocean areas (Southwest Indian Ocean, Northwest Pacific, etc.) Storms that cross from one area to another keep their original name, unless remnants from one storm reform into a new storm in the second area.

For all six lists, plus lists for other areas of the world, visit https://public.wmo.int/en/our-mandate/focus-areas/natural-hazards-and-disaster-risk-reduction/tropical-cyclones/Naming

Questions

1. Why do you think the different meteorological agencies use different terms for similar wind speeds?
2. What are some challenges that might arise from using different words for the same type of storm? (Consider multi-national corporations or international aid organizations.)
3. What are some other terms you have heard related to large storms? What do they mean, and who is using them?
4. Why do you think the National Hurricane Center switched to names instead of latitude and longitude for hurricanes?
5. What are some challenges that might arise from using human names for storms, especially across areas that include many countries?
6. Why do you think the WMO decided to create the supplemental lists instead of using the Greek alphabet?

Today I Learned About Hurricanes

"We don't really understand what sets the frequency of hurricanes even in the current climate very well... The two things I'd say we're confident about... the storms will be more intense. The storms will have stronger winds. When you put greenhouse gases in the atmosphere, the ocean not only warms up, but the rate of evaporation of seawater increases. The other thing we're completely confident of is that a given storm will rain more, because that's very simple physics: the warmer the air, the more water vapor it can hold. "

Professor Kerry Emanuel, MIT Department of Earth, Atmospheric and Planetary Science

TILclimate podcast: Today I Learned About Hurricanes

Historical Data

Since the mid-1800s, we have been adding large amounts of carbon dioxide (CO_2) to the atmosphere from the burning of fossil fuels such as coal, oil, and natural gas and cutting down of forests. This CO_2 acts like a blanket, trapping heat. Heat is absorbed by the land, ocean, and air. We know that warmer sea temperatures can lead to stronger storms.

As climatologists and meteorologists look to model future hurricane seasons, they look to the past to see how patterns have changed since the start of the industrial revolution and the dramatic increase in CO_2 emissions to the atmosphere. Consider the following data for Atlantic hurricane seasons from 1851-2020.

Interpretation

1. Using the data on the following pages, graph the pattern of storms since 1851.
2. What patterns do you notice?
3. Have the total number of storms changed over time?
4. Have the number of major storms (defined as categories 3, 4, or 5) changed over time?
5. Given the patterns that you identified, what would you expect the next decade's hurricane seasons to look like?
6. What other questions do you have about hurricanes? Where might you look for that information?

Today I Learned About Hurricanes

Year	Total Tropical Storms	Total Hurricanes	Major Hurricanes (Cat. 4&5)
1851	6	3	1
1852	5	5	1
1853	8	4	2
1854	5	3	1
1855	5	4	1
1856	6	4	2
1857	4	3	0
1858	6	6	0
1859	8	7	1
1860	7	6	1
1861	8	6	0
1862	6	3	0
1863	9	5	0
1864	5	3	0
1865	7	3	0
1866	7	6	1
1867	9	7	1
1868	4	3	0
1869	10	7	1
1870	11	10	2
1871	8	6	2
1872	5	4	0
1873	5	3	2
1874	7	4	0
1875	6	5	1
1876	5	4	2
1877	8	3	1
1878	12	10	2
1879	8	6	2
1880	11	9	2
1881	7	4	0
1882	6	4	2
1883	4	3	2
1884	4	4	1
1885	8	6	0
1886	12	10	4
1887	19	11	2
1888	9	6	2
1889	9	6	0
1890	4	2	1
1891	10	7	1
1892	9	5	0
1893	12	10	5
1894	7	5	4

Year	Total Tropical Storms	Total Hurricanes	Major Hurricanes (Cat. 4&5)
1895	6	2	0
1896	7	6	2
1897	6	3	0
1898	11	5	1
1899	10	5	2
1900	7	3	2
1901	13	6	0
1902	5	3	0
1903	10	7	1
1904	6	4	0
1905	5	1	1
1906	11	6	3
1907	5	0	0
1908	10	6	1
1909	12	6	4
1910	5	3	1
1911	6	3	0
1912	7	4	1
1913	6	4	0
1914	1	0	0
1915	6	5	3
1916	15	10	5
1917	4	2	2
1918	6	4	1
1919	5	2	1
1920	5	4	0
1921	7	5	2
1922	5	3	1
1923	9	4	1
1924	11	5	2
1925	4	1	0
1926	11	8	6
1927	8	4	1
1928	6	4	1
1929	5	3	1
1930	3	2	2
1931	13	3	1
1932	15	6	4
1933	20	11	6
1934	13	7	1
1935	8	5	3
1936	17	7	1
1937	11	4	1
1938	9	4	2

Data from the National Hurricane Center, https://www.nhc.noaa.gov/climo/images/AtlanticStormTotalsTable.pdf

Today I Learned About Hurricanes

Year	Total Tropical Storms	Total Hurricanes	Major Hurricanes (Cat. 4&5)
1939	6	3	1
1940	9	6	0
1941	6	4	3
1942	11	4	1
1943	10	5	2
1944	14	8	3
1945	11	5	2
1946	6	3	1
1947	9	5	2
1948	9	6	4
1949	13	7	3
1950	13	11	8
1951	10	8	5
1952	7	6	3
1953	14	6	4
1954	11	8	2
1955	12	9	6
1956	8	4	2
1957	8	3	2
1958	10	7	5
1959	11	7	2
1960	7	4	2
1961	11	8	7
1962	5	3	1
1963	9	7	2
1964	12	6	6
1965	6	4	1
1966	11	7	3
1967	8	6	1
1968	8	4	0
1969	18	12	5
1970	10	5	2
1971	13	6	1
1972	7	3	0
1973	8	4	1
1974	11	4	2
1975	9	6	3
1976	10	6	2
1977	6	5	1
1978	12	5	2
1979	9	5	2
1980	11	9	2
1981	12	7	3
1982	6	2	1

Year	Total Tropical Storms	Total Hurricanes	Major Hurricanes (Cat. 4&5)
1983	4	3	1
1984	13	5	1
1985	11	7	3
1986	6	4	0
1987	7	3	1
1988	12	5	3
1989	11	7	2
1990	14	8	1
1991	8	4	2
1992	7	4	1
1993	8	4	1
1994	7	3	0
1995	19	11	5
1996	13	9	6
1997	8	3	1
1998	14	10	3
1999	12	8	5
2000	15	8	3
2001	15	9	4
2002	12	4	2
2003	16	7	3
2004	15	9	6
2005	28	15	7
2006	10	5	2
2007	15	6	2
2008	16	8	5
2009	9	3	2
2010	19	12	5
2011	19	7	4
2012	19	10	2
2013	14	2	0
2014	8	6	2
2015	11	4	2
2016	15	7	4
2017	17	10	6
2018	15	8	2
2019	18	6	3
2020	30	14	7

Total Tropical Storms = All named storms in a year. Some become hurricanes.
Total Hurricanes = All hurricanes, categories 1-5.
Major Hurricanes = Hurricane categories 3-5.

Data from the National Hurricane Center, https://www.nhc.noaa.gov/climo/images/AtlanticStormTotalsTable.pdf

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Decade	Tropical Storm	Category 1	Category 2	Category 3	Category 4	Category 5
1851-1860	15	8	5	5	1	0
1861-1870	23	8	6	1	0	0
1871-1880	21	7	6	7	0	0
1881-1890	26	8	9	4	1	0
1891-1900	34	8	5	5	3	0
1901-1910	40	10	4	4	0	0
1911-1920	23	10	4	4	3	0
1921-1930	31	5	3	3	2	0
1931-1940	65	4	7	6	1	1
1941-1950	44	8	6	9	1	0
1951-1960	36	8	1	5	3	0
1961-1970	36	3	5	4	1	1
1971-1980	43	6	2	4	0	0
1981-1990	45	9	1	4	1	0
1991-2000	47	3	6	4	0	1
2001-2010	77	8	4	6	1	0
2011-2020	92	30	12	13	13	6
Wind Speeds	*39-73mph*	*74-95mph*	*96-110mph*	*111-129mph*	*130-156mph*	*>157mph*

Data from NOAA Technical Memorandum NWS NHC-6, 2011 https://www.nhc.noaa.gov/pdf/nws-nhc-6.pdf

Today I Learned About Hurricanes

"Creating hurricane-proof buildings and infrastructure is one option. There's also work to reinforce nature's ability to break storm surges or to absorb water, like with expanding wetlands."
Laur Hesse Fisher, MIT Environmental Solutions Initiative
TILclimate podcast: Today I Learned About Hurricanes

What Is Resilience?

When people talk about *climate resilience*, they usually mean a combination of three things:

1. Preparation: Building and adapting buildings, roads, and other infrastructure that can handle predicted extreme weather (high winds, rainfall, storm surge, etc.) and making sure that residents know what to do in case of a natural hazard.
2. Adaptation: Making zoning laws, insurance policies, etc. flexible enough to handle changes to patterns of natural hazards.
3. Recovery: Rapid response after a natural hazard to restore roads, buildings, and livelihoods so that residents' lives can return to normal.

In the case of hurricanes, resilience planning must include high winds, heavy rainfall, and flooding from rain and ocean storm surge. Engineers, ecologists, architects, and designers are working all over the world to protect their communities through natural systems, building design, and infrastructure development.

Design for the World We Want

On the following pages, find some ideas that communities around the world are using to make themselves more resilient in the face of hurricanes and other storms. With your group, discuss how you could design a hurricane-resilient community that you would want to live in.

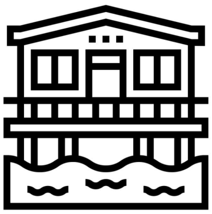
Consider:

- Does this design solve more than one problem, or give residents a benefit outside of hurricane season? (These solutions are often called *multisolving*.)
- Can this idea be applied to buildings that already exist, or does it need to be built new?
- Do you like how this design looks? Would you enjoy having it in your community?
- How does this design make a community resilient to the wind, rain, or storm surge of a hurricane?
- Communities are also resilient when they have the support and information they need to shelter in place, evacuate, return, clean up, and care for their members. What systems would help people in your imagined community get the information they need?

Today I Learned About Hurricanes

Solutions for Hurricane Resilience

Communities all over the world are developing and building solutions to protect people and places from the effects of increasing hurricane strength. The following examples are just a small selection of the innovative ideas that are improving resilience.



Rise Above Both storm surge (waves pushed by wind) and heavy rain can cause flooding. Buildings can be lifted (as on stilts) or have a first floor that can flood with limited damage.

Example: Spaulding Rehabilitation Hospital in Boston, MA
https://www.resilientdesign.org/how-to-make-a-hospital-resilient-a-tour-of-spaulding-rehabilitation-center/ or https://climate.mit.edu/ed/spaulding

Absorb Natural wetlands, such as salt marshes and mangrove swamps, slow down storm surge and absorb flooding. Communities can protect and restore these vital ecosystems.

Example: Mangrove restoration in Ft. Lauderdale, Florida
https://ocean.si.edu/ocean-life/plants-algae/mangrove-restoration-letting-mother-nature-do-work or https://climate.mit.edu/ed/Mangroves

Slow Down Natural and artificial coral reefs, oyster reefs, and other ocean-bottom structures act like a speed bump for waves. People can protect and restore these underwater communities.

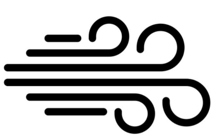
Example: Coral reef restoration in the Florida Keys
https://www.wbur.org/hereandnow/2020/09/18/saving-coral-florida-keys or https://climate.mit.edu/ed/coral

Hold Back Seawalls, hurricane gates, and levees can be a barrier to storm surge, protecting the spaces behind them.

Example: Seawalls in the National Parks
https://www.nps.gov/articles/seawalls-bulkheads-and-revetments.htm or https://climate.mit.edu/ed/seawalls

Live With Water Parks and other public spaces can be designed to hold flood water until it can naturally seep into the groundwater.

Example: Moakley Park in Boston, MA
https://dirt.asla.org/2021/05/20/moakley-park-the-inclusive-resilient-park-of-the-future/



Build for Wind Roofs, windows, and buildings can be designed or protected to resist, move with, or deflect wind.

Example: Affordable hurricane-resistant housing in Immokalee, Florida
https://www.naplesnews.com/story/news/local/2021/11/11/immokalee-florida-fair-housing-alliance-affordable-housing-project-underway/6181222001/ or https://climate.mit.edu/ed/housingflorida

Images from The Noun Project by Smalllike, Dan Hetteix, Coloripop, IronSV, Kmg Design, and Hanna Vernydub