Teacher Guide

Lesson 7: Warmed-up Storms

SKILLS:

Lesson question: What would past hurricanes be like if they happened in a warmer world?

Learning objectives:

- Students compare data from actual hurricanes and tropical storms with model data that represents what the same storms would be like in a world with a warmer climate, learning that storms will likely become windier and can cause more rainfall.

Timing: One class period

Materials:

- Classroom computer, projector, and Internet access
- Lesson 7 Slides: Warmed-up Storms (download from scied.ucar.edu/HurricaneResilience)
- *Storm Data Cards* for your region (also used in Lesson 4, download from scied.ucar.edu/HurricaneResilience)
- *Warmed-up Storm Data Cards* for the same region as the *Storm Data Cards* (download from scied.ucar.edu/HurricaneResilience)
- Table tents with storm names
- Student page: *What would hurricanes and tropical storms be like in a warmer world?* (page 57)
- Markers (one for each student)
- Long paper strips for writing headlines (one for each student)
- Driving Question Board (used in previous lessons)

Preparation:

- At the Hurricane Resilience website (scied.ucar.edu/HurricaneResilience), locate the collection of *Warmed-up Storm Data Cards* from the same region as the *Storm Data Cards* you used for Lesson 4. Data Card collections are available for seven locations along the U.S. Gulf, Caribbean, and Atlantic coasts. Choose the one that is closest to your location to help students focus on their region.
- Print the data cards and set up stations around the room with the cards and table tents that note each storm name. Alternatively, have the PDFs of *Warmed-up Storm Data Cards* and *Storm Data Cards* available on computers for students to access and compare.
- Make copies of the student page - one for each student.
- Review the slides.

Directions

Introduction

- Have students review what they have learned in Lessons 4-6:
  - The most hazardous aspects of hurricanes (such as wind, rain, and flooding) (Lesson 4)
  - Hurricanes worldwide are getting stronger as climate warms (Lesson 5)
  - Climate change is causing sea level rise, which is making our coast more vulnerable (Lesson 6)
- Show the climate stripes (**Slide 2**) to remind students that climate has been warming, which is why hurricanes are getting stronger and the reason that global sea level is rising. Note that climate is predicted to continue warming in this century. While estimates vary, sometime later this century, global climate will be 2°C warmer.

- Ask students: What do you think those storms would be like if they happened in a world that was 2°C warmer? (**Slide 3**) Explain that we can answer this question by comparing the characteristics of the actual storms with storms modeled as if they happened in the same location but in a warmer world. Modeling can allow us to get an idea of what future hurricanes might be like. This is one way that climate scientists figure out how warmer temperatures will affect hurricanes.
- Computer models that take into account lots of different parts of the Earth system (**Slide 4**) are used to predict how climate is likely to change in the future, and they can also be used to predict how climate warming will affect hurricanes.
- These simulations model the atmosphere, land, ocean, and ice around the world. This takes a lot of computing speed, so it's done with supercomputers (**Slide 5**).
- Show students an image of a simulated hurricane (**Slide 6**) and explain that this is not an actual hurricane; it was generated with a computer model.

Compare actual and warmed-up storms.

- Show **Slide 7** to remind students of the question that they will explore with data analysis (What if historical storms happened again in a world that is warmer by 2°C?) If possible, leave the slide projected while students complete the data analysis.
- Introduce the data stations to students. (Stations around the room for each hurricane and tropical storm in the set.)
- Give each student a copy of the *What would hurricanes and tropical storms be like in a warmer world?* student page and introduce the instructions. Describe that students should compare the actual storm to the warmed-up version. Go over an example at one of the stations together as a class before sending students to the stations to explore the data.
  - **Wind:** Introduce the warmed-up wind map, which was generated with a computer model. students should compare the max wind of the warmed-up storm and actual storm.
  - **Footprint:** Remind students how to measure the footprint using the wind map. They'll measure and compare the footprint of the actual and warmed-up storms.
  - **Rain:** Tell students that we know that rainfall increase by 7% per degree Celsius of warming, so in a 2°C warmer world, there would be 14% more rain. Multiply the storm's max rain by 1.14 to estimate the max rain of the warmed-up storm.
  - **Flooding:** Remind students that sea level rise is affecting the water level. If you are using hurricane data from your region, students can add the estimate of sea level rise for their region that they found in Lesson 6 to the max water level.
- Provide at least 10 minutes for students to visit stations around the classroom. Students may not have time to visit every station, but they should be able to discern the pattern if they visit three or more stations.

Draw conclusions from the data analysis.

- Pass out long strips of paper and markers, one per student.
- Have each student write a headline to sum up what happens to hurricanes in a warmer world. Remind students that a good headline is catchy but, more importantly, it gets at the heart of the issue.
- Have students hang their headlines on the wall. Show **Slide 8** and have students discuss what they found. (*No matter which hurricane or tropical storm they analyzed, students will find that rainfall, winds, storm footprint, and flooding increase in a warmer world.*)

Review what we know and what we don't yet know about how hurricanes are changing.

- Describe what scientists know.
  - **Slide 9**: The amount of rainfall is increasing as climate warms.
  - **Slide 10**: Hurricane winds are getting stronger as climate warms.
  - **Slide 11**: Storms surge is increasing both because sea level is rising and because stronger winds push more water onto land during hurricanes.
- Describe what scientists are still investigating.
  - **Slide 12**: Are the numbers of hurricanes and tropical storms changing?
  - **Slide 13**: What if hurricanes slowed down?

Update the Driving Question Board.

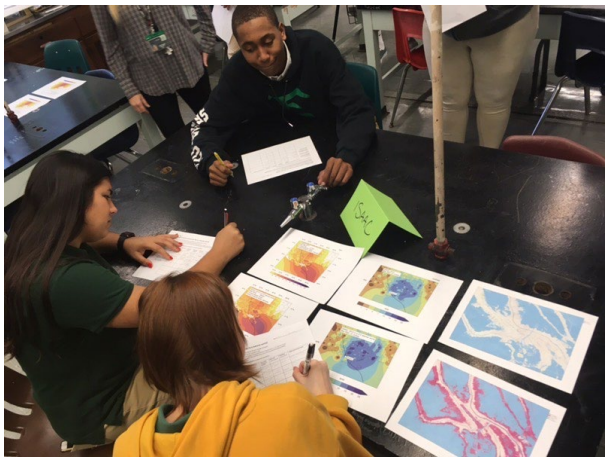
- Have students return to the Driving Question Board to see whether there are questions that can now be answered or questions that should be changed based on what we know now. Have students consider whether they have new questions to add to the board now that they have investigated the impacts of climate change on how hurricanes and sea level will likely affect the coast in the future.

Opportunities for Assessment

- Student work on the student page will reflect their ability to compare and contrast the actual storm data and the data from "warmed up" storms.
- Headlines that students write after their data analysis should reflect understandings built during data analysis: that in a warmer climate, storms have higher winds, more rainfall, and cause more flooding.
- Give students the Hurricane Resilience Quiz 2 to assess learning through the end of Lesson 7 (Part 2). Assessments can be downloaded from the Hurricane Resilience Assessments google folder.

Teacher Notes

- Science tells us that rainfall rates increase by 7% per degree Celsius of warming. To a good approximation the total storm rainfall increases by 14% under 2°C of warming. Note that this change in rainfall ignores any other potential changes to hurricanes in a warmer world. For example, if hurricanes slow down their approach to the coast then this can also increase total rainfall. In fact, a hurricane that halves its forward speed will double its rainfall totals, all other things being equal.
- Sea level rise will contribute to increasing hurricane surge heights in the future. In fact, seas have already risen along our hurricane-prone coastlines. This means that peak water levels for recent historical storms are higher than they otherwise would be without recent sea level rise. Note that adding sea level rise to water levels during actual storms does not account for the possibility that stronger storms in the future, would cause more storm surge. They also don't account for other potentially important factors for peak water height such as erosion, subsidence, and future construction.
- Hurricanes obtain their energy from the warm oceans. A warmer ocean therefore contains more fuel for hurricanes. Scientists agree that wind speeds increase by approximately 5% per degree Celsius of warming, so about 10% for 2°C of warming. Damage typically increases three times as fast as the rising wind speeds, so a 10% increase in wind speed increases damage by 30%. Scientists are currently working to understand if eye width and forward speed of hurricanes are affected by climate warming.



Students at South Terrebonne High School, Houma, LA, compare maps of data from hurricanes and tropical storms with model data from the same storms in a warmer climate.

Name:

What would hurricanes and tropical storms be like in a warmer world?

Lesson 7 Student Page: Warmed-up Storms

To learn how hurricanes and tropical storms are affected by climate change, compare:

- data from actual storms that affected your region, and
- data calculated from model storms that simulate what would happen if the same storms happened in a 2°C warmer world.

Compare the actual and model storms' footprint, wind, rain, and flooding data and record your findings in the table at the right.

Instructions:
Write the name of the storm at your station into a row of the table.

Measure the **footprint** on the actual wind map and the warmed-up storm wind map. Write the two numbers in the footprint column and note which is larger.

Compare the **max wind** from the actual and the warmed-up storm maps. Put the speeds in the wind column and note which is larger.

Find the **max rain** of the actual storm. Rainfall increase by 7% per degree Celsius of warming, so in a 2°C warmer world, rain would be 14% more. Multiply the storm's max rain by 1.14 to estimate the max rain of the warmed-up storm. Write the two numbers in the rain column and note which is larger.

Water levels will be higher in the future because of sea level rise. If you know how much sea level rise is expected in the region over this century (from Lesson 6), add it to the highest water level and write both in the column. Or provide an estimate, adding 1-3 feet to the water level for the warmed-up storm.

Move to another station and repeat.

Name of the hurricane or tropical storm	**Footprint** (compare maps)	**Max wind** (compare maps)	**Max rain** (calculate - see instructions)	**Flooding** (calculate - see instructions)