Hurricanes and Hot Towers with TRMM - Teacher Guide

Lesson Overview: Students will think about their experiences with hurricanes and severe storms, and then learn the basics of what causes hurricanes to form. Students will learn how hurricane prediction has progressed, and how satellite technology is used to see inside storms to get improved data for enhancing computer-based mathematical models. To share what they've learned, students will create a news report (script or comic strip) to tell others about hurricanes and hurricane prediction.

The lesson is expected to take one to two 45 minute periods, or one 90-minute block.

Learning Objectives:

- Students will be able to list the factors that cause hurricanes to form.
- Students will be able to describe how various types of data (including from satellites such as TRMM, the Tropical Rainfall Measuring Mission) help improve the prediction of hurricane tracks and intensity.

National Standards:

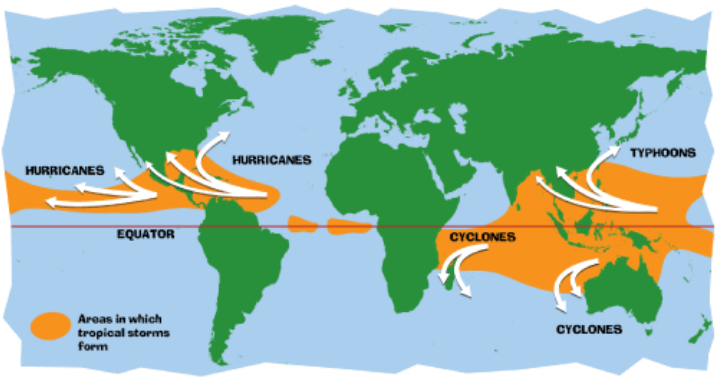
ESS3.B: Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events.

MS-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects. [Clarification Statement: Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts).

From the Next Generation Science Standards, available at http://www.nextgenscience.org/

Background Information:

"Hurricanes are the most awesome, violent storms on Earth. They form near the equator over warm ocean waters. Actually, the term hurricane is used only for the large storms that form over the Atlantic Ocean or eastern Pacific Ocean.



The generic, scientific term for these storms, wherever they occur, is tropical cyclone. Other names they are given, depending on where in the world they are born, are typhoons, cyclones, severe tropical cyclones, or severe cyclonic storms. Whatever they are called, the same forces and conditions are at work in forming these giant storms, which all can cause damage or devastation when they hit land where people live.
Tropical cyclones are like engines that require warm, moist air as fuel. So the first ingredient needed for a tropical cyclone is warm ocean water. That

is why tropical cyclones form only in tropical regions where the ocean is at least 80 F for at least the top 50 meters (about 165 feet) below the surface.

The second ingredient for a tropical cyclone is wind. In the case of hurricanes that form in the Atlantic Ocean, the wind blowing westward across the Atlantic from Africa provides the necessary ingredient. As the wind passes over the ocean's surface, water evaporates (turns into water vapor) and rises. As it rises, the water vapor cools, and condenses back into large water droplets, forming large cumulonimbus clouds. These clouds are just the beginning."

Text and image from: http://scijinks.jpl.nasa.gov/hurricane

Other sources of background information:

- Hurricanes . . . Unleashing Nature's Fury http://www.nws.noaa.gov/om/hurricane/pdfs/HurricanesUNF07.pdf
- Tropical Twisters – Hurricanes: How They Work and What They Do http://kids.earth.nasa.gov/archive/hurricane/index.html
- What are Hurricanes? http://www.nasa.gov/audience/forstudents/5-8/features/what-are-hurricanes-58.html
- Hurricanes: The Greatest Storms on Earth http://earthobservatory.nasa.gov/Features/Hurricanes/hurricanes_1.php

Materials:

- Projector and screen or TV to show PowerPoint and animations, or sufficient computers if you prefer that students view the PowerPoint on their own, in pairs or a small group.
- Copies of the Hurricanes and Hot Towers with TRMM – Student Capture Sheet.

Engage: Using Hurricanes and Hot Towers with TRMM – Presentation, ask students: "Have you ever experienced a hurricane or a severe storm? What was it like?" (*slide 3*) Use these questions as a way to start a discussion to get at students background knowledge and prior experiences, to give them a context for this lesson. Pictures will appear when you click, which is useful if students are having trouble coming up with ideas.

Show students some of the effects of hurricanes (*slides 4-6*), to emphasize the importance and relevance of studying hurricanes.

Explain: The video "Fuel For The Storm" (*slide 7)* explains the three factors needed for hurricanes to form: warm water, moist air, and converging winds, http://oceantoday.noaa.gov/fuelforthestorm/, (length 2:19). Students can use the video and the review slide afterward (*slide 8)* to take notes on the Hurricanes and Hot Towers with TRMM – Student Capture Sheet. Show students the areas in which tropical storms form (*slide 9*), and a few more images of hurricane destruction (*slide 10),* to lead in to idea of hurricane prediction. We need to know the path of a hurricane to warn people who might be affected (*slide 11).* The image links to the website for the National Hurricane Center from the National Weather Service, http://www.nhc.noaa.gov/, which will have the most current information if advisories are being issued. A track forecast cone represents the probable track of a tropical cyclone (*slide 12)*, and is changed as scientists get new data about the storm. The image links to an animation of the progression of forecast cones for Hurricane Katrina, available at http://www.nhc.noaa.gov/archive/2005/KATRINA_graphics.shtml.

Explore: The next series of slides points out the progress we have made in predicting hurricanes, starting with the days when we only had ground observations, and very little way to warn people if they were in danger (*slide 13)*. The image links to more information about the Great Galveston Hurricane of 1900, which remains the most deadly natural disaster in U.S. history. http://celebrating200years.noaa.gov/magazine/galv_hurricane/welcome.html

Later, ships at sea were able to transmit information to shore via radio, and we developed radar and aircraft capable of flying through hurricanes to give us more data to put in computer-based mathematical models to help with predictions (*slide 14)*. Click on the image of the radar tower or radar data to go to a brief description of NOAA's radar research, http://youtu.be/hUm83vk8smo (length 0:39). The image of the plane links to an animation of the NASA's Global Hawk aircraft scanning a storm to monitor eyewall development, http://youtu.be/5VODtQCx8Fc (length 0:40).

Now we have satellites that can track the storm the entire time it is active, greatly improving our ability to predict the path of a hurricane (*slide 15)*. The diagram shows the improvement in the ability to predict the track of a hurricane using TRMM. The image links to a video about forecasting hurricanes, leading into the coming discussion about forecasting the intensification of hurricanes, http://youtu.be/MmEdgKjf7Hs (length 2:09). Satellites can show us the storm clouds as they move across the ocean, as in the animation linked from the image on *slide 16*, http://scijinks.jpl.nasa.gov/hurricane-Katrina (length 1:00).

Satellites such as TRMM (and soon its successor GPM - the Global Precipitation Measurement mission), can provide significant data about precipitation from space (*slide 17*). For more details about TRMM in general and the specific instruments, see http://trmm.gsfc.nasa.gov/overview_dir/background.html. The TRMM satellite can use microwaves to provide data about where in the clouds the heaviest rainfall is found (*slide 18*). TRMM can also use radar to see inside the storm (*slide 19*). The combination of this data gives use a more complete picture of hurricanes (*slide 20*).

Scientists have identified "hot towers" using radar, which has helped them develop insight into what causes hurricanes to intensify. These "hot towers" often occur before the storm gets stronger (*slide 21*). The image links directly to an animation looking at Hurricane Bonnie (length 0:52). Other formats are available at http://svs.gsfc.nasa.gov/goto?1150. The video "Towers in a Tempest" is a narrated animation that explains recent scientific insights into how hurricanes intensify, as caused by the phenomenon called "hot towers" (*slide 22*), http://gpm.nasa.gov/education/videos/towers-tempest (length 4:20).

Evaluate:
To have students process and share what they know, they will create a news report or weather forecast (performed with a script or created as a comic strip – see Hurricanes and Hot Towers with TRMM – Student Capture Sheet for a comic strip template), telling people about a hurricane that's coming and how we know where it will hit and if it will intensify (*slide 23*). A sample rubric is available at the end of this *Teacher Guide.*

If you wish to have students learn about hurricane preparedness for their news report or comic strip, "Hurricanes…Unleashing Nature's Fury" (http://www.nws.noaa.gov/om/hurricane/pdfs/HurricanesUNF07.pdf) is a great resource. Or show "Hurricane Survival" from NOAA (*slide 26*, in the "Extension Activities" section), which is a video with dramatic scenes of storms and tips about how to prepare for a hurricane,

http://oceantoday.noaa.gov/hurricanesurvival/ (length 3:08). Other preparedness information is available at http://www.nhc.noaa.gov/prepare/wwa.php.

Some ideas for students to consider including (*slide 24*):

- How is hurricane forecasting different now than it used to be?
- Imagine being a weather forecaster in two different areas of the coast, one in the direct path of the hurricane and one only near it. What would be different about what you tell people about the storm?
- How does our knowledge of a storm change as it gets closer? How might that change what you need to tell people?
- *Optional:* How should people prepare for a hurricane?

Elaborate/Extend:

- Show students graphs comparing improvements in predictions of hurricane tracks and intensity (*slide 27*). You can point out to students that there is a clear decrease in the error (measured in nautical miles off the actual track of the hurricane) since 1970. You might also point out how much more variation there is in the lines for predictions further away from landfall (120 hours and 96 hours), but that the data is much tighter for closer-range predictions like 24 hours, showing how much more accurate they are. There is less of an obvious trend in the intensity errors graph, showing how much improvement there is to make in that sort of prediction. For more information, see: http://www.nhc.noaa.gov/verification/verify5.shtml

- Show the video "TRMM at 15: The Reign of Rain" to explain the far-reaching applications TRMM has enabled for precipitation science in general, beyond hurricanes (*slide 28*), http://gpm.nasa.gov/education/videos/trmm-15-reign-rain (length 3:16). When the GPM core satellite launches in early 2014, it will increase the range and precision for precipitation measurements compared to TRMM. The main GPM website is found at: http://ppm.nasa.goc/GPM. For an animation of the satellites in the GPM constellation and how they work together to give a precipitation reading every three hours, go to: http://gpm.nasa.gov/education/videos/global-precipitation-measurement-constellation

- For more about storm surge, see the video on *slide 29,* http://oceantoday.noaa.gov/hurricanestormsurge/ (length 2:35) or visit http://www.nhc.noaa.gov/surge/

- For a connection to storms on other celestial bodies, you could show students a narrated video about a hurricane-like storm seen at Saturn's north pole by NASA's Cassini spacecraft. (length 1:36) http://www.nasa.gov/mission_pages/cassini/whycassini/cassini20130429.html

- Students could read an article about a study to determine why some storms (such as Tropical Storm Erin in 2007) intensify when they begin passing over land, instead of weakening the way most storms do. http://www.nasa.gov/content/goddard/brown-ocean-can-fuel-inland-tropical-cyclones

- Another article that might be of interest is about a study that shows polar-orbiting satellite data was key to pinpointing Sandy's track and time of landfall. http://www.noaanews.noaa.gov/stories2012/20121211_poesandsandy.html

- Kids may be interested in more about the hurricane hunters aircraft An article can be found at http://www.noaa.gov/features/03_protecting/hurricanehunterstory_2012.html and a video http://oceantoday.noaa.gov/hurricanehunters/ (length 2:14)

- A longer video, plus some additional footage of NASA's Global Hawk aircraft from the Hurricane and Severe Storm Sentinel (HS3) mission, can be found at http://svs.gsfc.nasa.gov/goto?11039

- For more about NOAA's National Severe Storms Lab's Radar Research, see http://youtu.be/g1MUxphxYJs (length 5:27)

Additional Resources:

- For a more comprehensive look at hurricanes and their formation, try "Ocean Explorer: Hurricanes" http://oceanexplorer.noaa.gov/edu/learning/player/lesson14.html

- For the latest storm images and data from NASA, visit http://www.nasa.gov/mission_pages/hurricanes/main/index.html

- Science on a Sphere- Forecast: Tropical Cyclones, script and datasets: http://sos.noaa.gov/Education/forecast.html

- More NASA videos about hurricanes can be found at http://www.youtube.com/user/NASAgovVideo/search?query=hurricane

- Links to additional data visualizations and other educational resources can be found at http://www.nasa.gov/mission_pages/hurricanes/features/hurricane_educ_links.html.

- Information about the Great Galveston Hurricane of 1900, which killed more people than any other natural disaster in U.S. history, can be found at http://celebrating200years.noaa.gov/magazine/galv_hurricane/welcome.html

- A fascinating book about the Great Galveston Hurricane is Isaac's Storm: A Man, a Time, and the Deadliest Hurricane in History by Erik Larson (ISBN 978-0375708275), which also includes interesting background about the early National Weather Service.

- To read about another famous historical hurricane, see Sudden Sea: The Great Hurricane of 1938 by R.A. Scotti (ISBN 978-0316832113). The progression of the ability to forecast hurricanes (or lack thereof) between the two books is especially interesting.

Rubric: Hurricane News Story or Comic Strip

	Advanced (4)	Proficient (3)	Partially Proficient (2)	Basic (1)	Points
Hurricane Formation	• Includes a definition or explanation of hurricanes and how they form	• Includes a definition, but lacks details or has minor errors in content	• Definition is attempted, but with major errors in content	• Minimal attempt or not included	
Hurricane Prediction	• Explains how we collect data about hurricanes, and how prediction of hurricane track and intensity has changed over time (especially with satellites)	• Includes description and data, but lacks details or has minor errors in content	• Description is attempted, but missing many details or with major errors in content	• Minimal attempt or not included	
Optional: Hurricane Preparedness	• Describes in detail what should be done to prepare for a hurricane.	• Preparedness is described, but lack details, or have minor errors in content	• Description is attempted, but missing many details or with major errors in content	• Minimal attempt or not included	
Neatness/Presentation	**For script:** • Writing is clear and shows thought and care • Presentation of script it excellent – easy to hear, well-practiced, engaging **For comic:** • Drawing and captions are neat and show thought and care. • Something is added to make the viewer/reader say "wow, that's great!"	**For script:** • Writing is clear and shows thought and care • Presentation of script is good, but could use improvement or practice. **For comic:** • Drawing and captions are neat and show thought and care.	**For script:** • Shows some effort to write clearly and give presentation well – is okay, but needs lots of work. **For comic:** • Drawing and captions show some effort at neatness and clarify, but need a lot of work.	**For script:** • Shows very poor effort at writing and presenting. **For comic:** • Shows poor effort at drawing and writing neatly and clearly.	

With optional hurricane preparedness information:

Rubric Pts	16	15	14	13	12	11	10	9	8	7	6	5	4 or less
% Grade	100	96	92	88	84	80	76	72	68	64	60	55	50

Without optional hurricane preparedness information:

Rubric Pts	12	11	10	9	8	7	6	5	4	3 or less
% Grade	100	95	90	85	80	75	70	65	60	50