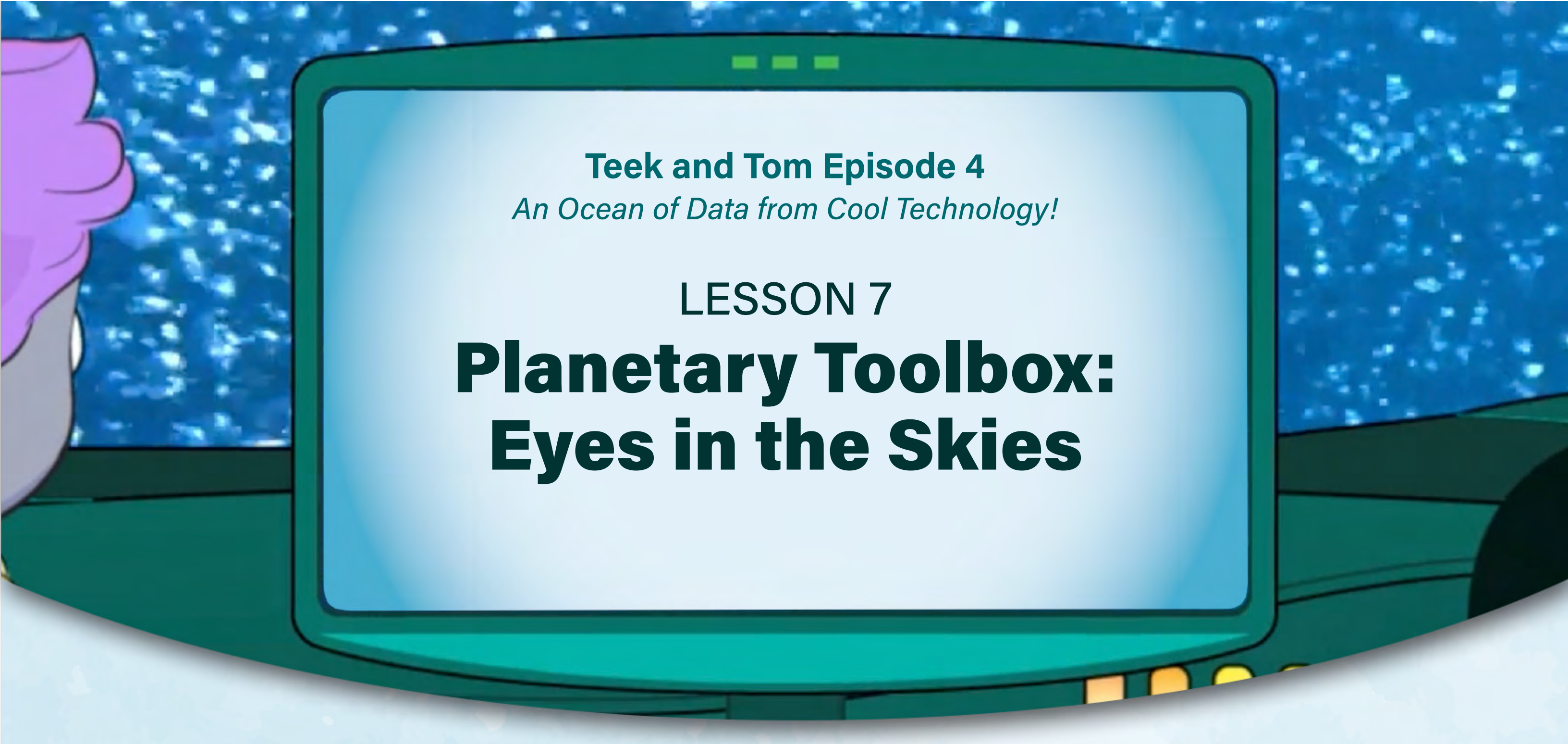


Teek and Tom Episode 4

An Ocean of Data from Cool Technology!

LESSON 7

Planetary Toolbox: Eyes in the Skies

All URLs were reviewed and accurate at the time of this lesson's publication. If you should come across a non-operational link, contact NOAA Ocean Service Education at oceanserviceeducation@noaa.gov. All images are credited to NOAA unless otherwise noted.

Introduction

In episode 4, scientist Tom introduced technology that NOAA uses to study the Earth's atmosphere. He discussed satellites that monitor Earth from space, hurricane hunter aircraft that use dropsondes, the RAAVEN drone, and weather balloons that measure atmospheric properties.

Earth-orbiting satellites provide continuous images and data on atmospheric conditions. They allow scientists to make more accurate and timely weather forecasts and better understand long-term climate conditions. Atlantic and Pacific geostationary satellites (GOES) can continuously observe hurricanes from formation to dissipation. They orbit 22,236 miles above Earth's equator at speeds equal to the Earth's rotation. This allows them to maintain their positions over specific geographic regions so they can provide continuous coverage of that area over time.

Two polar-orbiting satellites (POES) circle the Earth in north-south orbits, passing close to the North and South Poles. The POES satellite system makes 14 polar orbits per day, traveling approximately 520 miles above the Earth. As the POES satellites circle the Earth, the planet rotates beneath them. This allows the satellites to see a different view with each orbit, with each satellite providing two complete views of weather around the world every day. Often called the backbone of global weather forecasting, polar-orbiting weather satellites fly closer to the Earth than geostationary satellites. They provide as much as 85% of the data used by weather models.

GOES and POES satellites allow scientists to track atmospheric variables such as temperature and cloud formation, providing data necessary to track and understand normal weather patterns, as well as extreme weather events like hurricanes.

To gather data around, within, and above hurricanes, NOAA uses its own aircraft as well as aircraft operated by the U.S. Air Force. These planes routinely fly into potentially threatening storms where their radar and sensors measure a cross-section of the hurricane. They also use dropsondes to gather information about the layers of the hurricane.

There are 122 NOAA National Weather Service (NWS) weather forecast offices around the country. Meteorologists at these offices supplement the information provided by NOAA and U.S. Air Force aircraft with data provided by ground weather radar stations. Together, these systems let meteorologists measure the motion inside storms and hurricanes and record their precipitation intensity, movement, and a variety of wind data.

The NOAA NWS also launches weather balloons to collect information about atmospheric conditions and improve weather forecasts — especially those involving extreme weather like hurricanes. A small expendable box of instruments connected to the balloons called a radiosonde measures air temperature, pressure, humidity, as well as wind speed and direction. A radio signal sends data back to scientists on the ground. During its flight, a weather balloon can reach over 100,000 feet in altitude. Eventually, at a very high altitude, the balloon bursts. About 70,000 balloons are released by the NWS each year. Radiosondes provide valuable information to better understand the general behavior of the atmosphere and the formation of extreme weather.

The RAAVEN (**R**obust **A**utonomous **A**erial **V**ehicle-**E**ndurant and **N**imble) aircraft has been used in tropical places like Barbados. It is launched from a catapult and has sensors installed to measure wind and turbulence in the local clouds. The data it collects helps us to better understand how tropical clouds form. These cloud systems contain moisture and heat that are transported into the atmosphere around the globe. They can also form tropical cyclones and hurricanes that can affect coasts.

Lesson Summary

Students will learn about tools routinely used to observe general atmospheric conditions, as well as track and predict the impacts of hurricanes. Using data from a real hurricane event, they will work in teams to share information about a storm event and then develop emergency actions that should be taken before the hurricane makes landfall.

Objectives

- Students will be able to identify instruments that provide data about general atmospheric conditions as well as the development and movement of hurricanes.
- Students will be able to explain how teams work together to gather data and issue warnings to local populations about severe weather events like hurricanes.

Estimated Time

It is estimated that one to two 45-minute class periods are needed for each lesson. This does not include the time required to view Episode 4 of Teek and Tom *"An Ocean of Data from Cool Technology!"*, 12:23 minutes (https://oceantoday.noaa.gov/teekandtom/episode-4.html).

Education Standards

The lessons that accompany the Teek and Tom series were designed for upper elementary and middle school students. The standards addressed are abbreviated here. A full list of standards is available in Appendix A (https://oceantoday.noaa.gov/teekandtom/educators-guide/appendix-a.pdf).

Next Generation Science Standards

- 3-ESS3-1: Earth and Human Activity. Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.
- MS-ESS3-2: Earth and Human Activity. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

Common Core English and Language Arts: Writing Standards Grades 4-5

Common Core Mathematics: Measurement and Data - Represent and interpret data.

College, Career, and Civic Life (C3) Framework for Social Studies: Geographic Representations

Materials

For a class of 30

- Team data sheets for the simulation
- Small rulers that measure up to 6 inches
- Students will need printouts of student record sheets, graphs, and/or maps to carry out the activities. Student record sheets are located at the end of this lesson.
- If you would like to provide the maps/graphics on a projection system, students will only need the student record sheets. Depending on the configuration of your classroom, we recommend one set per student or group.
- All maps/graphics presented in the activity are available as a slide set to project or present while teaching these activities. (https://oceantoday.noaa.gov/teekandtom/educators-guide/slide-set-7.zip)

Preparation

No special preparation is needed for this lesson.

InvesTeekation Pathway

ENGAGE

Part 1. Engage

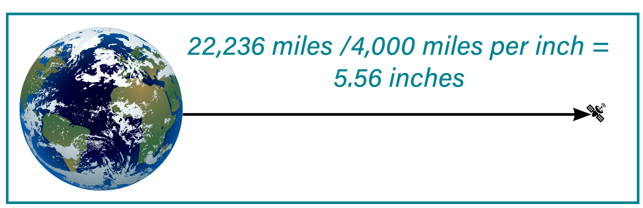
NOAA NWS watches and warnings may be issued for a wide variety of weather events. These include wind, hurricanes, thunderstorms, tornadoes, floods, heat, fog, wind chill, frost, freeze, ice storms, and fire. Students should compare the information provided for a severe thunderstorm watch versus a warning and then discuss their thoughts in small groups.

EXPLORE

Part 2. Explore

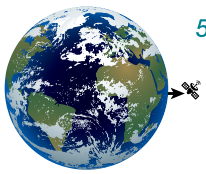
Students will be introduced to the technology tools highlighted in episode 4 of Teek and Tom and will answer questions about each. The answers are below.

1. Geostationary satellites hold their position above Earth. The 2-inch Earth image represents our planet's 8,000-mile (12,874 kilometers) diameter. Each inch represents 4,000 miles. How many inches away would the geostationary satellite be? In the answer box, measure that distance from the Earth and mark where the (tiny) satellite would be.



Credit: Shutterstock

2. If we use the same 2-inch Earth, calculate how far away a polar-orbiting satellite would orbit at 520 miles. Remember, each inch represents 4,000 miles. In the answer box, measure that distance from the Earth and mark where the (tiny) satellite would be.



520 miles /4,000 miles per inch = 0.13 inches

Credit: Shutterstock

3. A map of the U.S. shows the locations and names of NOAA National Weather Service (NWS) forecast offices around the country and the regions they cover. Find the name of the NWS forecast office in your area. *Answers will vary.*

4. During its flight, a weather balloon can reach an altitude of over 100,000 feet (19 miles). Balloons rise about 4 meters per second (9 miles per hour). How long would it take a weather balloon to rise 19 miles? *19 miles / 9 miles per hour = 2.1 hours.*

5. If a weather balloon sends back two measurements of the atmosphere each second, calculate how many measurements it would collect from the time it's launched from the ground until it reaches an altitude of 19 miles. *2 measurements x 60 seconds x 60 minutes x 2.1 hours = 15,120 measurements*

6. The RAAVEN (**R**obust **A**utonomous **A**erial **V**ehicle-**E**ndurant and **N**imble) aircraft is launched from a catapult and has sensors installed to measure wind and turbulence in the local clouds. What is one advantage and one disadvantage of using drones like RAAVEN compared to larger aircraft or satellites for gathering data? *ROVs like RAAVEN are cheaper to operate and can be launched from many places. RAAVEN cannot withstand the intense conditions present in a hurricane.*

7. Show students this video: NOAA's Hurricane Hunters Fly Into the Eye of a Monster (https://oceantoday.noaa.gov/hurricanehunters/). What are the similarities and differences in the information provided by hurricane hunters compared to satellites, the RAAVEN, and weather balloons? *Hurricane hunters can record temperature, pressure, and wind speed from individual layers within the hurricane. Satellites can only show the top of the hurricane. Weather balloons have a limited area to collect data. RAAVEN and hurricane hunters gather data on winds and conditions inside cloud formations. Satellites can derive temperature, pressure, and wind speed from other variables.*

EXPLAIN

Part 3. Explain

Hurricane Florence, a large and slow-moving hurricane, made landfall during the morning of September 14, 2018. The storm spent two days producing record-breaking rainfall (30 inches) across eastern North Carolina and a portion of northeastern South Carolina. Record river flooding destroyed roads and damaged thousands of homes and businesses. Although Florence will be remembered primarily for its record-breaking flooding, wind gusts over 100 mph caused significant damage to buildings, trees, and electrical service. Your students will use actual data collected from this hurricane to predict the impacts of this event. Additional information about Hurricane Florence can be found in the slide set that accompanies this lesson.

Divide your students into five teams, assigning each team to one of the five roles below.

- NOAA Satellite team will report the location of the hurricane.
- NOAA Hurricane Hunter team will report the top wind speeds of the hurricane.

- NOAA NWS office in Wilmington, North Carolina, will report the wind speed and rainfall amounts.
- NOAA NWS National Hurricane Center team 1 will issue hurricane watches and warnings.
- NOAA NWS National Hurricane Center team 2 will issue storm surge and tornado watches and warnings.

During the hurricane, NOAA Hurricane Hunters conducted nine flights. Data and imagery from land-based NOAA Doppler weather radars and satellites, like the NOAA polar-orbiting satellites, were used to construct Hurricane Florence's best track and impact. Point out the eye at the center of the hurricane image.

Provide each team with the six daily reports relevant to their team for September 9-14. Each team will share their data with the class. Students will also complete a data table and map the hurricane's progress. You can provide a sheet containing the six days of reports or cut the sheets apart so that each team gets a small stack of six reports.

The slide set for this lesson (https://oceantoday.noaa.gov/teekandtom/educators-guide/slide-set-7.zip) includes images of the hurricane's path and its anticipated track, as well as storm surge and rainfall information. You can present the relevant information to the class for each date of the simulation. The images include:

- September 9 – Hurricane track with anticipated path
- September 10 – Hurricane track with anticipated path
- September 11 – Hurricane track with anticipated path
- September 12 – Hurricane track with anticipated path and estimated storm surge map
- September 13 – Hurricane track with anticipated path and rainfall map
- September 14 – Hurricane track with anticipated path

Earth Curiosities

Killer Hurricane

The 1900 Galveston Hurricane was the deadliest weather disaster in United States history. On September 8 the storm hit the Texas coast south of Galveston as a Category 4 hurricane. Storm tides, a combination of regular tides and storm surge, of 8 to 15 feet swamped Galveston Island and other parts of the Texas coast. These storm tides were the primary cause of the 8,000 deaths on record, though death toll estimates from the storm range from 6,000 to 12,000. Photo Credit: Library of Congress

Storm surge is a rise in coastal water levels due to a hurricane. It is the greatest threat to life and property from a hurricane. Extreme flooding in coastal areas happens when normal high tides combine with a storm surge.

NOAA Satellite Team

September 9

Hurricane is located at 24.5 north latitude and 55.8 west longitude

NOAA Satellite Team

September 10

Hurricane is located at 24.9 north latitude and 58.9 west longitude

NOAA Satellite Team

September 11

Hurricane is located at 26.4 north latitude and 64.1 west longitude

NOAA Satellite Team

September 12

Hurricane is located at 28.5 north latitude and 69.5 west longitude

NOAA Satellite Team

September 13

Hurricane is located at 32.5 north latitude and 74.3 west longitude

NOAA Satellite Team

September 14

Hurricane is located at 34.1 north latitude and 77.2 west longitude

NOAA Hurricane Hunters

September 9

Hurricane top wind speeds of 76 mph

Hurricane eye has a diameter of 12 miles

NOAA Hurricane Hunters

September 10

Hurricane top wind speeds of 140 mph

Hurricane eye has a diameter of 12 miles

NOAA Hurricane Hunters

September 11

Hurricane top wind speeds of 140 mph

Hurricane eye has a diameter of 36 miles

NOAA Hurricane Hunters

September 12

Hurricane top wind speeds of 140 mph

Hurricane eye has a diameter of 34 miles

Storm is 400 miles in diameter

NOAA Hurricane Hunters

September 13

Hurricane top wind speeds of 110 mph

Hurricane eye collapses

NOAA Hurricane Hunters

September 14

Hurricane top wind speeds of 90 mph

There is no eye to report

NOAA National Weather Service Office

Wilmington, NC – September 9

Average ground wind speed of 4-10 mph

Precipitation: 0 inches of rain

NOAA National Weather Service Office

Wilmington, NC – September 10

Average ground wind speed of 5-13 mph

Precipitation: 0 inches of rain

NOAA National Weather Service Office

Wilmington, NC – September 11

Average ground wind speed of 6-12 mph

Precipitation: 0.02 inches inches of rain

NOAA National Weather Service Office

Wilmington, NC – September 12

Average ground wind speed of 5-15 mph

Precipitation: 0.60 inches inches of rain

NOAA National Weather Service Office

Wilmington, NC – September 13

Average ground wind speed of 30-40 mph

Precipitation: 1.50 inches inches of rain

NOAA National Weather Service Office

Wilmington, NC – September 14

Average ground wind speed of 60-105 mph

Precipitation: 9.58 inches of rain with over 30 inches in some areas

National Hurricane Center – Team 1

September 9

Tropical storm watch issued for coastal North Carolina

National Hurricane Center – Team 1

September 10

Hurricane watch issued for coastal North Carolina and Virginia

National Hurricane Center – Team 1

September 11

Hurricane warning issued for coastal North Carolina and Virginia

National Hurricane Center – Team 1

September 12

Hurricane warning issued for coastal North Carolina and Virginia

National Hurricane Center – Team 1

September 13

Hurricane warning issued for coastal North Carolina and Virginia

National Hurricane Center – Team 1

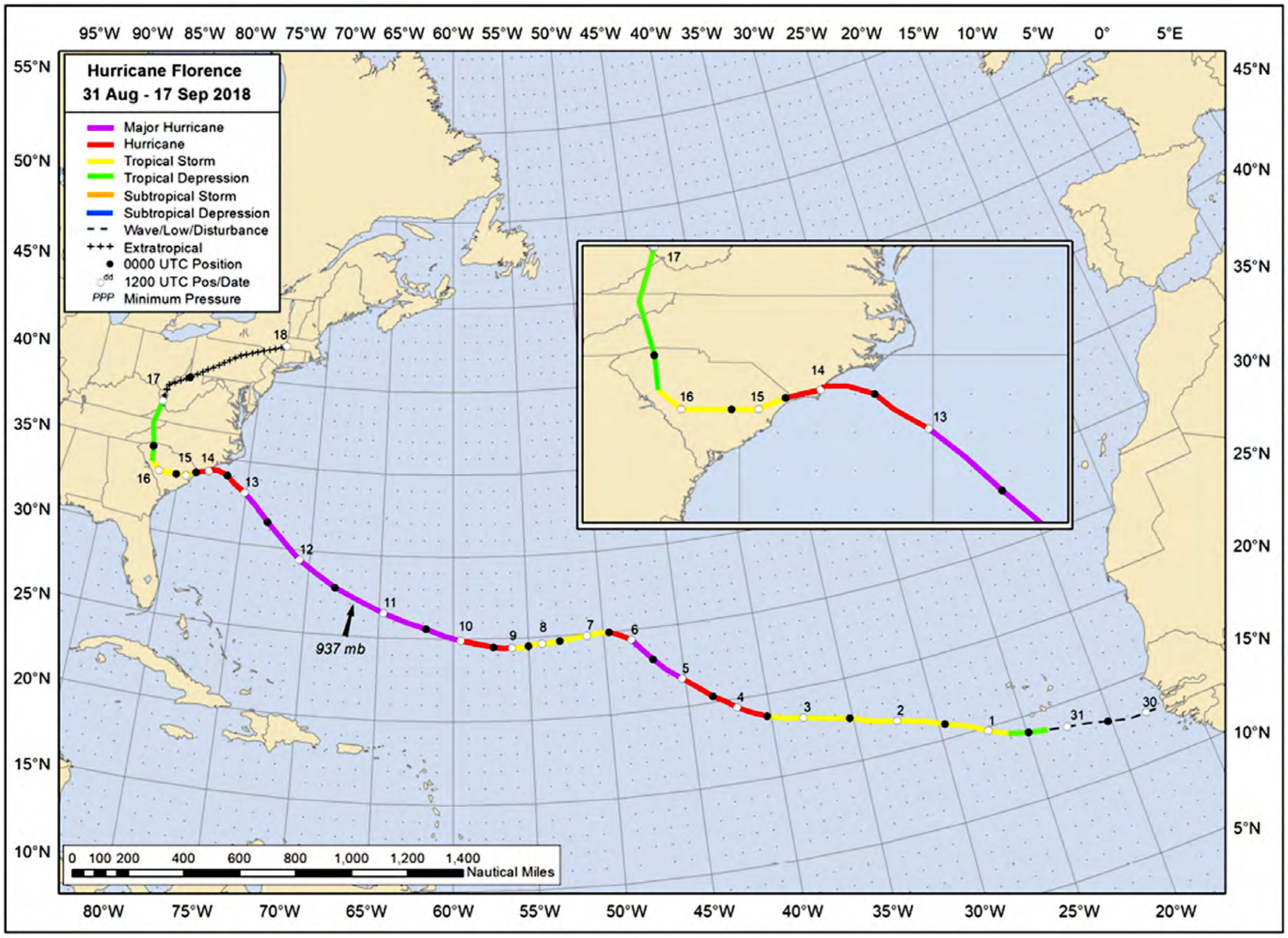
September 14

Hurricane warning replaced with tropical storm warning coastal North Carolina and Virginia

National Hurricane Center – Team 2 **September 9** Storm surge watch issued for coastal North Carolina	**National Hurricane Center – Team 2** **September 10** Storm surge watch predicted 8 to 11 feet above ground level for coastal areas of North Carolina and South Carolina
National Hurricane Center – Team 2 **September 11** Rainfall exceeding 10 inches predicted for coastal North Carolina	**National Hurricane Center – Team 2** **September 12** Tornado watch for coastal and inland North Carolina Storm surge warning for coastal areas of North Carolina and South Carolina
National Hurricane Center – Team 2 **September 13** Tornado watch for coastal and inland North Carolina Storm surge warning for coastal areas of North Carolina and South Carolina	**National Hurricane Center – Team 2** **September 14** Tornadoes warnings over North Carolina and South Carolina Storm surge warning of 4 feet above normal levels for coastal areas of North Carolina and South Carolina

The table below shows team information for all dates.

Team	NOAA Satellite	NOAA Hurricane Hunter	NOAA NWS office Wilmington, NC	NOAA National Hurricane Center team 1	NOAA National Hurricane Center team 2
Date	**Location**	**Hurricane wind speed; Size of the hurricane's eye or size of the whole hurricane**	**Wind speed on the ground; Precipitation**	**Tropical depression, tropical storm, or hurricane**	**Storm surge, anticipated rainfall, and wind warnings**
Sept 9	*24.5 N 55.8 W*	*76 mph* *Eye diameter: 12 miles*	*Wind speed: 4-10 mph* *Precipitation: 0*	*Tropical storm watch NC*	*Storm surge watch issued for SC/NC*
Sept 10	*24.9 N 58.9 W*	*140 mph* *Eye diameter: 12 miles*	*Wind speed: 5-13 mph* *Precipitation: 0*	*Hurricane watch NC/VA*	*Storm surge watch predicted 8 to 11 ft above ground level for SC/NC*
Sept 11	*26.4 N 64.1 W*	*140 mph* *Eye diameter: 36 miles*	*Wind speed: 6-12 mph* *Precipitation: 0.02 inches*	*Hurricane warning NC/VA*	*Rainfall exceeding 10 inches predicted for NC*
Sept 12	*28.5 N 69.5 W*	*140 mph* *Eye diameter: 34 miles* *Storm diameter: 400 miles*	*Wind speed:* *5-15 mph* *Precipitation: 0.60 inches*	*Hurricane warning NC/VA*	*Tornado watch for NC* *Storm surge warning for SC/NC*
Sept 13	*32.5 N 74.3 W*	*110 mph* *Eye collapses*	*Wind speed: 30-40 mph* *Precipitation: 1.50 inches*	*Hurricane warning NC/VA*	*Tornado watch for NC* *Storm surge warning for SC/NC*
Sept 14	*34.1 N 77.2 W*	*90 mph*	*Wind speed: 60-105 mph* *Precipitation: 9.58 inches* *30 inches in some areas*	*Hurricane warning replaced with tropical storm warning NC/VA*	*Tornado warnings SC/NC* *Storm surge warning SC/NC* *Storm produced 31 tornadoes over North Carolina and South Carolina September 15-16.*



By the end of the storm, wind gusts over 100 mph caused significant damage to buildings, trees, and electrical service. A storm surge of over 4 feet eroded beaches and damaged property. The hurricane caused 42 fatalities. An estimated 74,563 structures were flooded, and 5,214 people were rescued from flooding.

Once the data has been collected from each team, ask the students to work in their small groups to complete the table about emergency responses for each day. Based on the data collected each day, what actions do they think should be taken to prepare for the storm and keep everyone safe? The hurricane affected a large area over several states. Ask students to consider the actions that individuals and state and local officials should take, how hospitals and airports should prepare, and who should evacuate to be safe. Think about the need for fresh water, food, electricity, and shelter in a tornado. Also, ask students how they would prepare for flash flooding, which happens when heavy rainfall occurs over a short amount of time, such as several hours or successive days, filling streams and rivers. Brainstorm some potential actions with students that can be taken each day for emergency preparations. These might include:

- Make plans to evacuate
- Evacuate
- Move to higher ground
- Stock up on water, groceries, gas, and supplies
- Prepare for high winds
- Prepare for flash floods
- Prepare for loss of power
- Hospitals and nursing homes should be ready with a generator
- Airports may need to shut down
- Move to tornado shelters

Date	Emergency Response and Preparation
September 9	*People in North Carolina should stock up on water, groceries, and supplies. They should make plans in case they need to evacuate.*
September 10	*People who live close to the coast should evacuate. People who live farther inland should stock up on groceries, gas, and supplies.*
September 11	*People in low-lying areas that can flood should evacuate. Coastal areas of North Carolina and South Carolina should evacuate.*
September 12	*People should prepare for high winds, flood waters, and losing power. People who live in low-lying areas or on the coast should move to shelter in higher areas or in special community centers.*
September 13	*People should prepare for high winds, flood waters, and losing power. People in mobile homes should be prepared to go to tornado shelters. Hospitals and nursing homes should be ready with generators. Airports may need to shut down.*
September 14	*Residents and visitors should remain indoors until local officials decide it is safe to go outside. If a tornado warning is issued, people should take shelter in the lower part of their houses, and people in mobile homes should go to tornado shelters.*

ELABORATE

Part 4. Elaborate

Debrief Questions

1. Why is taking multiple measurements of the wind speed, precipitation in the clouds, storm direction, and other data important?

   More data means that scientists can make more accurate predictions and provide information many days ahead of time for emergency preparations.

2. Why is coordination critical between the different data sources, such as hurricane hunters, satellite teams, local weather stations, and the National Hurricane Center?

   Each team collects different information. When combined, the results provide a more accurate and complete picture of the storm and its effects.

3. Why is it important to inform the local population about the various effects of approaching severe weather?

   The storm affects people differently depending on where they live. Watches and warnings need to be issued to everyone for all impacts of the storm so they can take action and help those who might not be aware of the warnings.

EVALUATE

Part 5. Evaluate

The students have a self-assessment to evaluate how well they think they performed in the simulation. The rubric below is for evaluating student performance by the teacher.

CATEGORY	Exemplary	Proficient	Partially Proficient	Unsatisfactory	Points
Focus on the Task	**3 points**	**2 points**	**1 point**	**0 points**	
	Stayed on task all of the time without reminders.	Stayed on task most of the time. Group members can count on this person.	Stayed on task some of the time. Group members must sometimes remind this person to do the work.	Hardly ever stays on task. Will let others do the work.	
Work Habits	**3 points**	**2 points**	**1 point**	**0 points**	
	Completed assigned tasks and does not depend on others to do the work.	Completed most assigned tasks.	Does not follow through on most tasks and sometimes counts on others to do the work	Does not complete tasks. Depends on others to do all of the work.	
Listening, Questioning, and Discussing	**3 points**	**2 points**	**1 point**	**0 points**	
	Respectfully listens, discusses, asks questions, and helps the group.	Respectfully listens, discusses, and asks questions.	Has trouble listening with respect and does not take turns.	Does not listen with respect, argues with teammates, and does not consider other ideas.	
Information-Sharing	**3 points**	**2 points**	**1 point**	**0 points**	
	Gathered information and shared useful ideas.	Usually provided useful information and ideas for discussion.	Sometimes provided useful information and ideas for discussion.	Almost never provided useful information or ideas for discussion.	
Group/Partner Teamwork	**3 points**	**2 points**	**1 point**	**0 points**	
	All team members contributed equally.	Assisted group/ partner in the finished project.	Finished individual tasks but did not assist the group/ partner during the project.	Contributed little to the group effort during the project.	
				TOTAL POINTS	____/15

All URLs were reviewed and accurate at the time of this lesson's publication. If you should come across a non-operational link, contact NOAA Ocean Service Education at oceanserviceeducation@noaa.gov.

Extensions

These additional Ocean Today Videos will be helpful for student understanding during discussions about hurricanes.

- Hurricane Survival Guide (https://oceantoday.noaa.gov/fullmoon-hurricanesurvival/welcome.html)
- Hurricane Storm Surge (https://oceantoday.noaa.gov/fullmoon-stormsurge/welcome.htm)

Student Record Sheets

PART 1.

You have probably experienced weather watches and warnings. NOAA's National Weather Service (NWS) issues watches and warnings for local areas. These may be issued for a wide variety of weather events. including wind, hurricanes, thunderstorms, tornadoes, floods, heat, fog, wind chill, frost, freeze, ice storms, and fire. Below are examples of a severe thunderstorm watch and a warning.

Severe Thunderstorm WATCH **Be Prepared!**	Severe thunderstorms are possible in and near the watch area. Weather conditions favor thunderstorms, damaging wind, and hail. The watch area is typically large, covering numerous counties or even states. The risk of hazardous weather has increased, but its occurrence, location, or timing is still uncertain. A watch is intended to give people enough advance notice to be prepared with a plan of action in case a storm threatens. Listen for later information and possible warnings, especially when planning travel or outdoor activities.

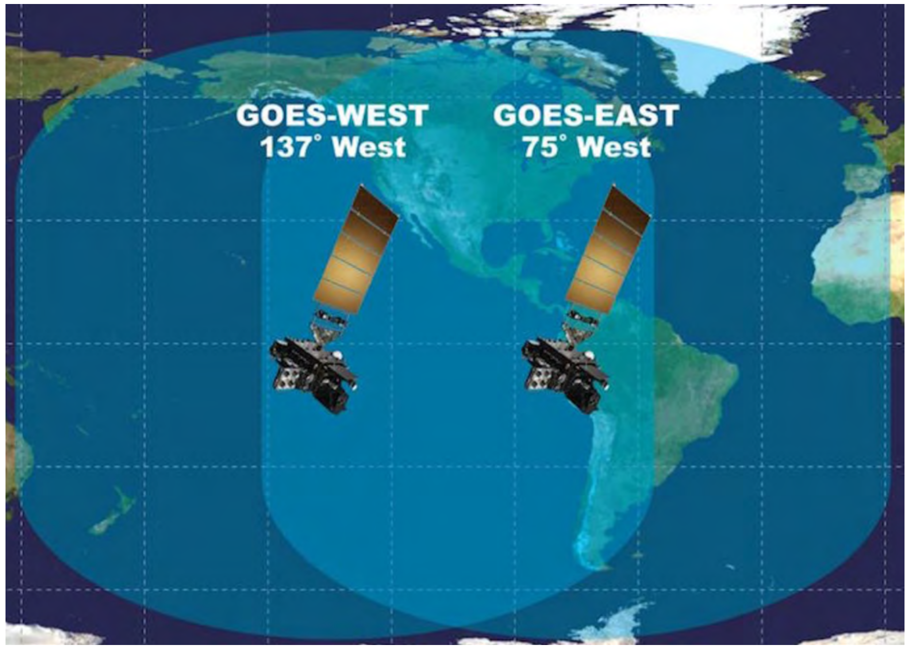
Severe Thunderstorm WARNING **Take Action!**	Severe weather has been reported by spotters or indicated by radar. Seek shelter. A warning means weather conditions pose a threat to life or property. People in the path of the storm need to take protective action. Large hail or damaging wind is occurring or will occur in this location. Take shelter in a substantial building. Get out of mobile homes that can blow over in high winds. Warnings typically are posted in a much smaller area — around the size of a city or small county — that may be impacted by a large hail or damaging wind identified by an NWS forecaster on radar or by a trained spotter/law enforcement watching the storm.

Compare the differences between a watch and a warning.

In a small group, discuss how you think a watch and a warning are different, and be prepared to explain your thinking.

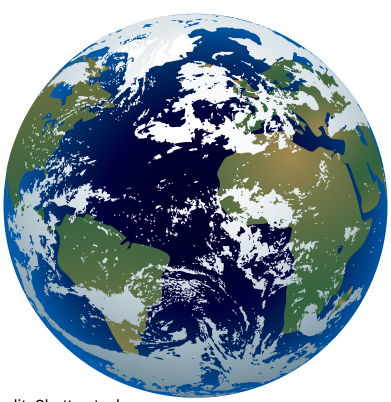
PART 2.

In episode 4, scientist Tom introduced technology that NOAA uses to study the Earth's atmosphere. He discussed satellites that monitor Earth from space, hurricane hunter aircraft that use dropsondes, the RAAVEN drone, and weather balloons that measure atmospheric properties. Two kinds of satellites allow scientists to collect data on atmospheric variables such as temperature and cloud formation. The information they provide allows scientists to track and understand weather patterns, as well as extreme weather events like hurricanes.



1. Geostationary satellites (GOES) orbit 22,236 miles above Earth's equator. Two of these GOES satellites provide imagery over North and South America as well as the Atlantic and Pacific oceans. During severe weather, geostationary satellites can be commanded to take images every 30 seconds to 1 minute. The image shows the two satellites hovering directly over North and South America.

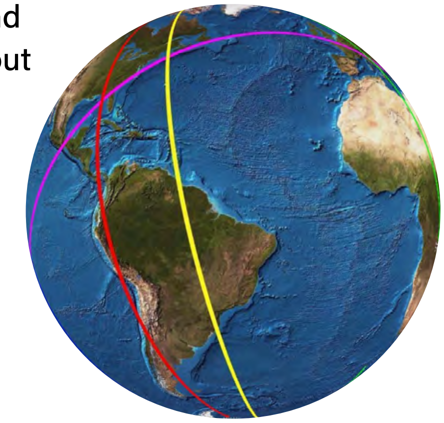
   Let's model the distance that geostationary satellites hold above Earth. This 2-inch image of the Earth represents our planet's 8,000-mile diameter. Each inch represents 4,000 miles. How many inches away would the geostationary satellites be? In the answer box, measure that distance away from the Earth and mark where the (tiny) satellite would be.

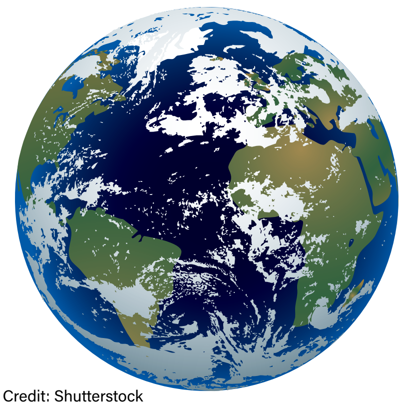


Credit: Shutterstock

2. Polar-orbiting satellites (POES) make orbits that circle the North and South Poles. They make nearly 14 polar orbits per day, traveling about 520 miles above the surface of the Earth. As the POES satellites circle the Earth, the planet rotates beneath them. This allows the satellites to see a different view with each orbit.

   If we use the same 2-inch Earth, calculate how far away a polar-orbiting satellite would orbit at 520 miles. Remember, each inch represents 4,000 miles. In the answer box, measure that distance away from the Earth and mark where the (tiny) satellite would be.

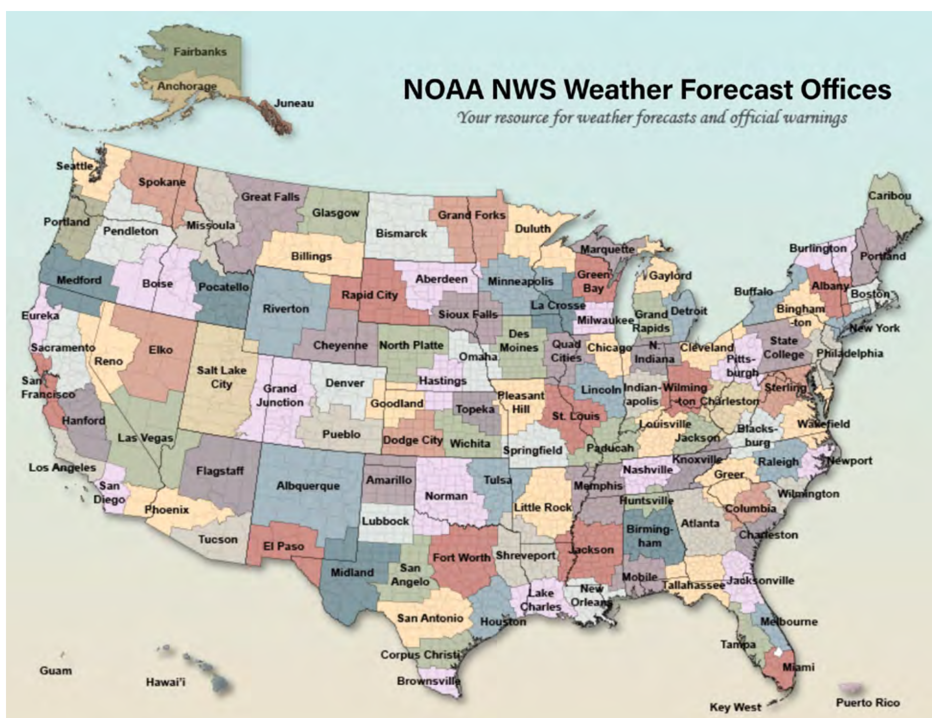




Credit: Shutterstock

3. There are 122 NOAA NWS forecast offices around the country. Local offices monitor local weather around the clock. They issue forecasts for their specific regions two to four times a day. They also provide information on hazardous weather that might impact their area. Local offices issue weather watches and/or warnings to alert people to any threats.

   Find the name of the NOAA NWS forecast office in your area.



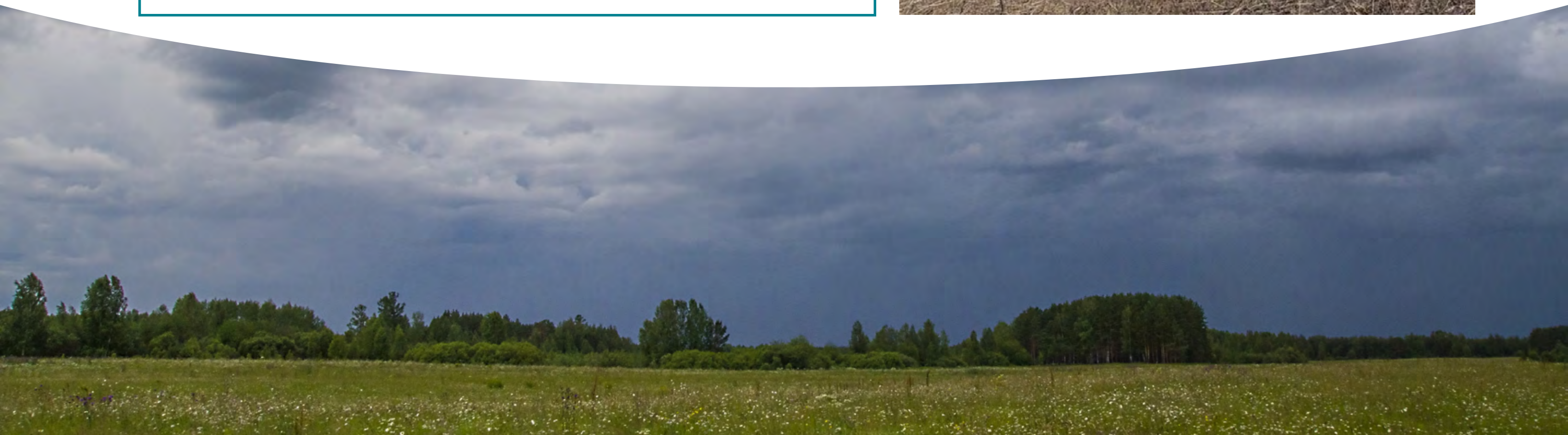
4. NOAA NWS regularly launches thousands of weather balloons from local offices to collect information that improves weather forecasts. These balloons carry instruments that measure temperature, air pressure, humidity, wind speed, and direction. A radio signal sends the data back to scientists on the ground. During its flight, a weather balloon can reach over 100,000 feet (19 miles) in altitude. Balloons rise about 4 meters per second (9 miles per hour). How long would it take a weather balloon to rise 19 miles?

A weather balloon is shown completely inflated, along with its parachute and the instrument package, known as a radiosonde.

5. If a weather balloon sends back two measurements of the atmosphere each second, calculate how many measurements it would collect from the time it's launched from the ground until it reaches an altitude of 19 miles.

6. The RAAVEN (**R**obust **A**utonomous **A**erial **V**ehicle-**E**ndurant and **N**imble) aircraft is launched from a catapult and has sensors installed to measure wind and turbulence in the local clouds. What is one advantage and one disadvantage of using drones like RAAVEN compared to larger aircraft or satellites for gathering data?

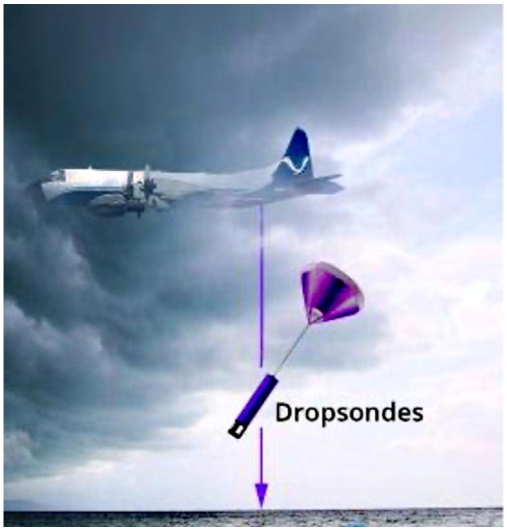
Credit: CIRES/NOAA



7. Hurricane Hunter aircraft fly into the world's worst weather. Data collected by these high-flying meteorological stations help forecasters make accurate predictions during a hurricane. They also help hurricane researchers develop a better understanding of storm processes to improve their forecast models.

   Watch the short video NOAA's Hurricane Hunters Fly Into the Eye of a Monster (https://oceantoday.noaa.gov/hurricanehunters/).

   What are the similarities and differences in the information provided by hurricane hunters compared to satellites, the RAAVEN, and weather balloons?



Fun Fact: NOAA has nicknamed their three hurricane hunter aircraft Miss Piggy, Kermit, and Gonzo, after the Muppets characters.

PART 3.

Hurricane!

You will be part of a team studying a weather disturbance in the Atlantic Ocean. You will work with that team to provide information using one of the technology tools that you've been learning about. The teams are:

- **NOAA Satellite team** – will report the location of the hurricane.
- **NOAA Hurricane Hunter team** – will report the top wind speeds of the hurricane.
- **NOAA National Weather Service office in Wilmington, North Carolina** – will report the wind speed and rainfall amounts.
- **NOAA National Weather Service National Hurricane Center team 1** – will issue hurricane watches and warnings.
- **NOAA National Weather Service National Hurricane Center team 2** – will issue storm surge and tornado watches and warnings.

The NOAA Hurricane Hunter team uses dropsondes during its flights to collect information from within the hurricane, such as the wind speed and the size of the eye. The eye is a circular area of fair weather found at the center of a severe tropical storm.

The NOAA Satellite team collects information from the GOES and POES satellites.

The NOAA National Weather Service local office sends weather balloons to collect localized data about the atmosphere. All of the information is fed to computers at NOAA's NWS National Hurricane Center.

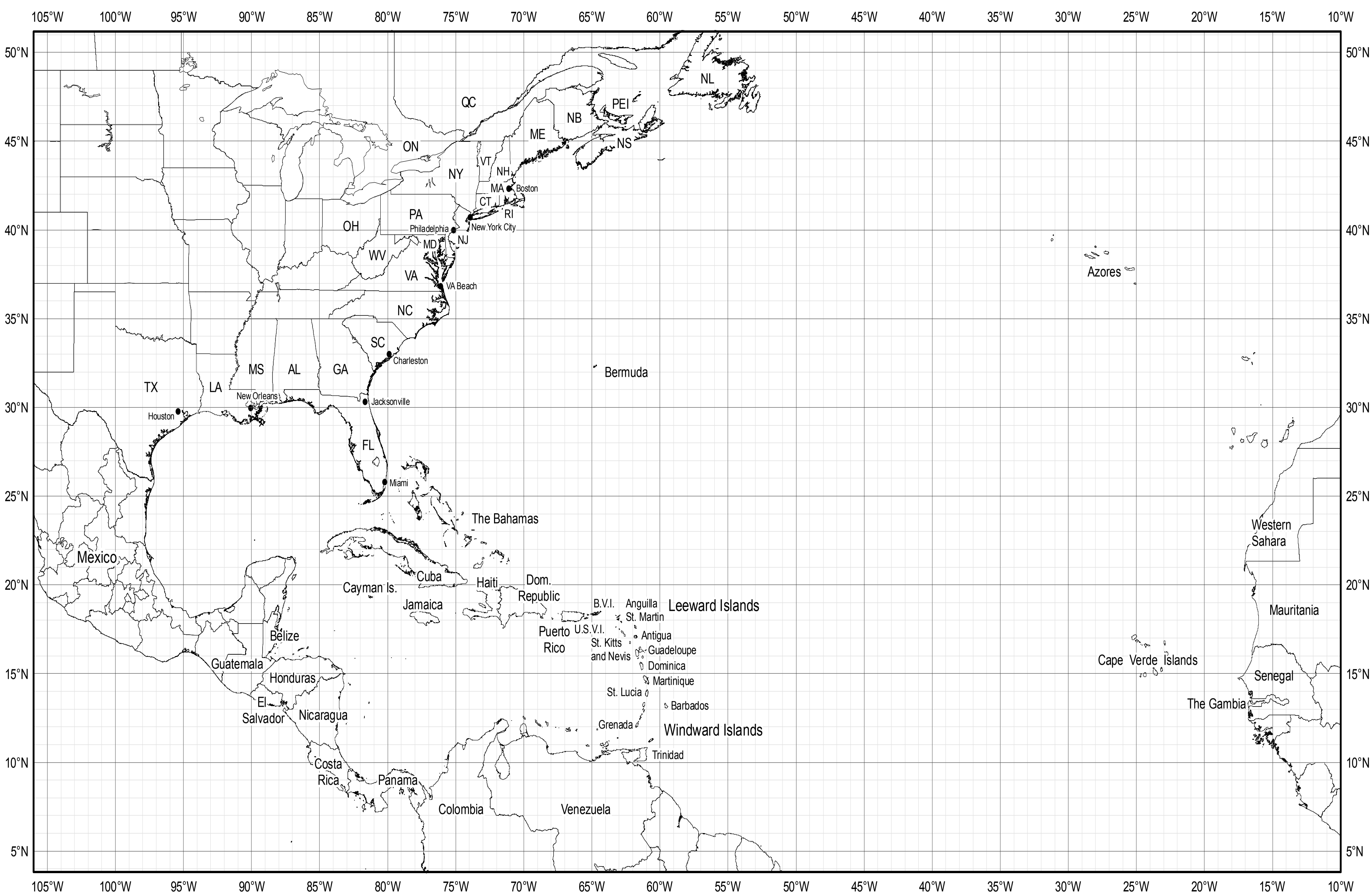
The NOAA National Hurricane Center issues watches and warnings to the places that need to know about approaching severe weather associated with hurricanes. They also predict the impacts of storm surge, rain, and wind. This simulation will help you see some of the work needed to warn people about the effects of an approaching hurricane.

Each team will be given information for six days of the simulation from September 9-14. Each team will share each day's information with the rest of the class. Everyone will record all of the information from each team so that you can help guide the emergency response needed to keep people safe. You should also map the location of the approaching storm on the Atlantic Hurricane Tracking Map.

Team	NOAA Satellite	NOAA Hurricane Hunter	NOAA NWS office Wilmington, NC	NOAA National Hurricane Center team 1	NOAA National Hurricane Center team 2
Date	**Location**	**Hurricane wind speed; Size of the hurricane's eye or size of the whole hurricane**	**Wind speed on the ground; Precipitation**	**Tropical depression, tropical storm, or hurricane**	**Storm surge, anticipated rainfall, and wind warnings**
Sept 9					
Sept 10					
Sept 11					
Sept 12					
Sept 13					
Sept 14					

Atlantic Basin Hurricane Tracking Chart

National Hurricane Center, Miami, Florida



Once the data has been collected from each team, work in your group to discuss and complete the table about emergency responses for each day.

Think about what actions should be taken by individuals or families to prepare for the storm and keep everyone safe. They may need fresh water and food for several days. They should be prepared to be without electricity. Safe places and shelters need to be identified for tornadoes.

What actions should local officials take to prepare hospitals and airports? Finally, consider who might help with repairs, restoring power, and helping clear the debris after the storm. Be prepared to share your advice with the class.

Date	Emergency Response and Preparation
September 9	
September 10	
September 11	
September 12	
September 13	
September 14	

PART 4.

Debrief Questions

1. Why is taking multiple measurements of the wind speed, precipitation in the clouds, storm direction, and other data important?

2. Why is coordination critical between the different data sources, such as hurricane hunters, satellite teams, local weather stations, and the National Hurricane Center?

3. Why is it important to inform the local population about the various effects of approaching severe weather?

PART 5.

Finally, think about how well your team did in the simulation and what you contributed to the group effort. Select the points in each category and record how you think you did. Select 0-3 points for each category and then total the points you think you earned.

CATEGORY	Exemplary	Proficient	Partially Proficient	Unsatisfactory	Points
Focus on the Task	**3 points**	**2 points**	**1 point**	**0 points**	
	Stayed on task all of the time without reminders.	Stayed on task most of the time. Group members can count on this person.	Stayed on task some of the time. Group members must sometimes remind this person to do the work.	Hardly ever stays on task. Will let others do the work.	
Work Habits	**3 points**	**2 points**	**1 point**	**0 points**	
	Completed assigned tasks and does not depend on others to do the work.	Completed most assigned tasks.	Does not follow through on most tasks and sometimes counts on others to do the work	Does not complete tasks. Depends on others to do all of the work.	
Listening, Questioning, and Discussing	**3 points**	**2 points**	**1 point**	**0 points**	
	Respectfully listens, discusses, asks questions, and helps the group.	Respectfully listens, discusses, and asks questions.	Has trouble listening with respect and does not take turns.	Does not listen with respect, argues with teammates, and does not consider other ideas.	
Information-Sharing	**3 points**	**2 points**	**1 point**	**0 points**	
	Gathered information and shared useful ideas.	Usually provided useful information and ideas for discussion.	Sometimes provided useful information and ideas for discussion.	Almost never provided useful information or ideas for discussion.	
Group/Partner Teamwork	**3 points**	**2 points**	**1 point**	**0 points**	
	All team members contributed equally.	Assisted group/ partner in the finished project.	Finished individual tasks but did not assist the group/ partner during the project.	Contributed little to the group effort during the project.	
				TOTAL POINTS	____/15