Environmental Science Institute
THE UNIVERSITY OF TEXAS AT AUSTIN

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Tracking Tempests

Lesson plan for grades: 6-8
Length of lesson: 2 class periods
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SOURCES AND RESOURCES:

- Hot Science Cool Talks, Hurricanes in the Gulf of Mexico: The History and the Future of the Texas Coast lecture by Dr. Kerry A. Emanuel
  http://www.esi.utexas.edu/k-12-a-the-community/hot-science-cool-talks/gulf-hurricanes-our-history-and-future
- CBS Interactive Hurricane Tutorial
  http://www.cbsnews.com/htdocs/natural_disasters/hurricanes/framesource.html
- E-Mission Hurricane Alert!
  http://www.e-missions.net/HurricaneAlert/?cat=72&sid=2&pid=113&page=Activity--Tracking%20a%20Hurricane
- National Hurricane Center
  http://www.nhc.noaa.gov/
- Sources for Hurricane Image in 1st worksheet
  http://scijinks.jpl.nasa.gov/hurricane and http://www.keyshistory.org/35-anatomy1.html
- Hurricane Tracking Map
  https://docs.google.com/viewer?url=http://www.e-missions.net/HurricaneAlert/includes/docs/storm_tracking_map_11x17.pdf
- Student Data Worksheet
  https://docs.google.com/viewer?url=http://www.e-missions.net/HurricaneAlert/includes/docs/studentTrackingWorksheet.pdf
- Hurricane Tracking Practice Worksheet
  https://docs.google.com/viewer?url=http://www.e-missions.net/HurricaneAlert/includes/docs/HurricaneTrackingStudentPractice.pdf
- Blank Hurricane Tracking Worksheet
  https://docs.google.com/viewer?url=http://www.e-missions.net/HurricaneAlert/includes/docs/Math%20Practice%20DATA%20WORKSHEET.pdf
- Cone of Uncertainty (Optional)
  https://docs.google.com/viewer?url=http://www.e-missions.net/HurricaneAlert/includes/docs/cone%20of%20uncertainty%20for%20Hurricane%20Alert.pdf

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- Answer Key for Hurricane Student Tracking Worksheet https://docs.google.com/viewer?url=http://www.e-missions.net/HurricaneAlert/includes/docs/HurricaneTrackingAnswerKey.pdf

POTENTIAL CONCEPTS TEKS ADDRESSED THROUGH THIS LESSON:

§112.18.b:1AB, 2ABCDE,
§112.19.b:1AB, 2ABCDE, 8AB
§112.20.b: 1AB, 2ABCDE,

PERFORMANCE OBJECTIVES (in order of increasing difficulty to permit tailoring to various age groups):

Students will be able to:

- Describe what factors contribute to the formation of a hurricane
- Predict the path of a hurricane using quantitative historical data and a working knowledge of meteorological factors that influence hurricane trajectories

MATERIALS (per group of four): (Numbers may be adjusted based on class size and budget)

- Laptops (Preferably one per student if available)
- The latest version of flash player and java available
- Pencils
- Heart of a Hurricane Worksheet (For Day 1, Attached)
- Tracking Tempests Worksheet (For Day 2, Attached)
- Hurricane Tracking map (at least 1 per person, depends how many times teacher wants students to track hurricane)

BACKGROUND:

Kerry Emanuel's January 6 2013 Hot Science – Cool Talks lecture deals with **hurricanes**, from the origin of the word to the tragedy of the Galveston Hurricane and what the future holds with climate change and hurricanes. These mighty storms are one of the most devastating natural disasters the United States has to contend with, as recent Hurricanes like Katrina, Ike and Rita have all shown.

While we can't stop a hurricane, we can predict where a hurricane will land by monitoring it via satellite and observing weather phenomena that can cause a change in direction of a hurricane. We can monitor a hurricane as it begins from its earliest stage of a **tropical depression** as it grows to **tropical storm** and ultimately a hurricane.

This lesson focuses on the subject of hurricane tracking by using various interactive websites and videos to help illustrate what conditions cause a hurricane to form and how meteorologists can predict the path of a hurricane.

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PREPARATION:

The teacher should have watched the entire lecture linked in the resource section to be familiar with what will be shown in the lesson and the topic of hurricanes in general. This lesson should be performed after the basic elements of weather are explained, specifically high and low pressure systems.

ENGAGE: (10 minutes)

Show the class the Kerry Emanuel Lecture that talks about the Galveston Hurricane, early weather tracking, and the damage it caused (33:18 to 40:15).

Then ask the following questions:

- What made the Galveston Hurricane particularly devastating compared to other hurricanes?
- Could there have been a way to reduce the devastation of the Galveston hurricane?
- How much do you think hurricane prediction has improved since the Galveston hurricane?

EXPLORE: (50 minutes)

The activity is based on the "Heart of a Hurricane" 3 part worksheet (see Materials) and supporting websites (see Sources and Resources). These materials should be passed out prior to the start of the Explore section of this lesson. It should also be introduced along the scenario described below. Students should be in groups already before starting the scenario:

NOAA, the National Oceanic and Atmospheric Administration, a part of the United States Department of Commerce, is looking for new meteorologists at the NHC, the National Hurricane Center. One thing that the NHC is responsible for is tracking hurricanes. As part of your application, you will need to learn the ins and outs of hurricanes and be able to predict the path of one, but only the best group will be selected as a "winner" in the job application process for the meteorologist positions.

The teacher will oversee the groups and answer any questions they have, but the worksheet is specifically designed for use in conjunction with the websites, Note that this worksheet's three sections require extensive work and attention to detail.

There is a "for teachers" link on this website, but it may not cover all questions; here are a few helpful hints to help direct students if needed:

- The colors represent wind speed, red being very strong and blue being very weak.
- The arrows represent the direction of the wind. They look like this: 
- Note that the arrow points in the direction of the top of the "L". For example, the above arrow is pointing west.

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At the end of Day 1, each group should give a short presentation explaining what causes hurricanes, how they are formed and what external factors influence the movement of a hurricane. Have the students turn in their worksheets since they are part of the formative assessment.

EXPLAIN: (50 minutes, Day 2)
Hand out the second worksheet set to the students, Tracking Tempests (see Materials), and have them complete it using their computers from last time, working in the same student groups. This lesson focuses on actually tracking the hurricane based off of past data and is a practice sheet.

It is up to the teacher's discretion whether to divide the students into specific "jobs" to make the activity more involved. Due to time constraints this lesson plan chooses to ignore this option, but for the teacher interested in expanding the activity, look to the Elaborate section for more ideas on this subject.

The "final test" is the last worksheet attached, "Tracking Tempest Test", which is a custom made hurricane simulation that will serve as the "indicator" on which group would get the hypothetical jobs. The hurricane used on the attachment is Hurricane Ike (2008), but the teacher is more than welcome to create their own hurricane path by using the NHC's Historical Hurricane Tracker:
http://csc.noaa.gov/hurricanes/#app=1834&3722-selectedIndex=1

The test can be executed in one of two years: As an entire class, where the teacher acts as the weather station and gives out the data at periodic intervals (best used if the teacher wishes to follow the Elaborate to expand the activity), or simply just hand them the Test worksheet with the Advisories already on it.

Note that the test uses the Hurricane Math Worksheet, the Hurricane Tracking Map and the Cone of Uncertainty (optional) in addition to the last worksheet.

ELABORATE: (20 minutes)

If there is enough time, the teacher may want to divide each person in a group to a specific job as outlined on the website:
http://www.e-missions.net/HurricaneAlert/?cat=72&sid=2&pid=160&page=Hurricane%20Tracking%20Practice

This option has been left out of the main activity to allow classes that won't fit the 4-team pattern or are short on time to still get the most out of the lesson.

Each group will present their projections to the class and the teacher will reveal the actual answer. While each group is presenting, ask them if they think they've seen this hurricane before or if the hurricane landed where they thought it would initially.

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Given time the teacher can show the NHC's actual model and show how incredibly complex the calculations can get in real life.

EVALUATE: Have students turn in the Worksheets & Exit quiz (see below). These are extensive worksheets for which mathematical computations are required in some areas.

Heart of a Hurricane Worksheet

Name:

Date:

PART 1:

The National Hurricane Center's main focus is Hurricanes, as the name suggests, and in order to track one, you need to know what exactly causes them to form, as well as what goes on when a hurricane occurs.

To start, visit the following website:
http://www.cbsnews.com/htdocs/natural_disasters/hurricanes/framesource.html
And click the link "Flash Animation: Hurricane 101: The Anatomy" and answer the following questions while watching it.

1) Where do most hurricanes in the Atlantic come from, and how do they start out? Is there a special region where hurricanes begin, and what makes this region special?

2) List the "ingredients", or weather conditions, needed for a hurricane to form.

3) What happens to form a hurricane once the appropriate ingredients are present? Draw a diagram (side view) of what happens, and label the steps in it.

4) Which way does a storm rotate, and what causes it to spin in that direction?

5) List all the stages of a storm and what characteristics each stage has. When does a storm get a name?

6) What is the name of the phenomena that moves the Hurricane west from North America?

7) What is the name of the region in the Atlantic that influences where a Hurricane will hit? How does this region affect the path of the Hurricane, and where will it hit depending on the condition of this factor?

8) What happens when a Hurricane makes landfall? What's the biggest cause of damage? What happens to the Hurricane as it continues over land?

9) Hurricanes have other telltale signs that they're coming besides strong wind and rain. What is one of these signs that can form hundreds of miles ahead of the hurricanes and describe it.

PART 2:
Put your hurricane knowledge to the test with a two part web test, hosted by the NHC:

A) First, let's create our own hurricane here:

http://www.nhc.noaa.gov/outreach/games/canelab.htm

Your job is to create the ideal conditions necessary for a hurricane to form. Write down what those conditions are as follows.

Wind Shear:

Humidity:

Latitude:

Sea Temperature (in Celsius):

What is the name of the storms from Africa that start a Hurricane?

We will take a more in-depth look on how a hurricane's path is changed by the weather, but for now we will review some basic weather definitions:

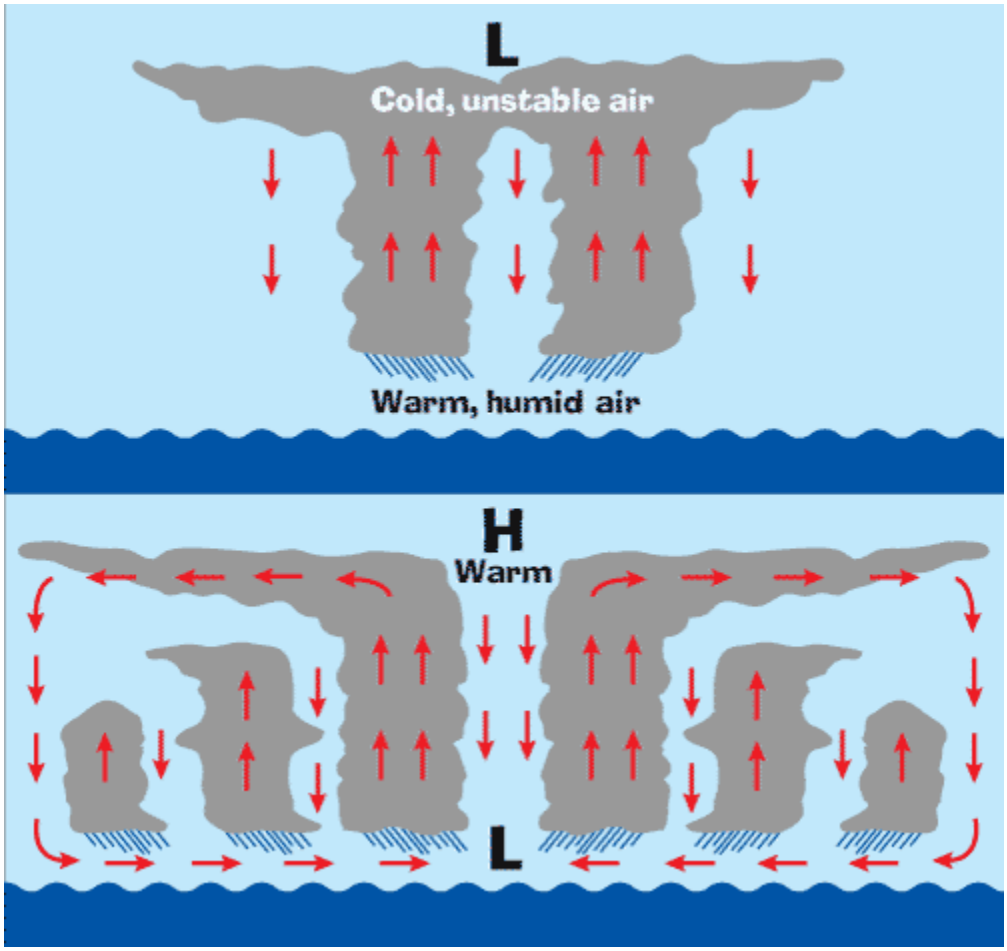
Low Pressure System: These systems usually produce cloudy, rainy weather. When a low pressure system enters an area, it causes the air to rise up, which cools the air (and the water in the air), causing condensation to occur and eventually precipitation. In a low pressure system the air flows in a counter clockwise direction (in the Northern Hemisphere).

High Pressure System: These systems usually produce fair weather. Typically, the air enters at high altitudes, sinks, and exits at ground level. The sinking motion causes warming and drying, often leaving a clear sky. These systems rotate clockwise (in the Northern Hemisphere)

Wait, how is this possible? The Coriolis Effect plays a big part of it, and this website is a good read for how it works: http://www.sjsu.edu/faculty/watkins/winddir.htm

What causes a High Pressure system to spin the opposite of the Earth's Rotation? Why does the Low Pressure System spin with the earth's rotation?

So what does this have to do with hurricanes? Take a different look at the formation of a hurricane with the following pictures:



Cross section of a hurricane showing wind currents

As you can see, Hurricanes are a bit more complicated than meets the eye. The Hurricane is actually rotating both counter-clockwise and clockwise near the Eye (the center and calm area of the phone), while the Coriolis Effect is what ultimately causes the overall spin of the Hurricane. This also explains the cycling effect that occurs within the hurricane.

PART 3:

How do these weather systems affect the path of a Hurricane? That is your job is to figure out with the Hurricane Simulator: http://www.nhc.noaa.gov/outreach/games/movncane.htm

Fill in the following table while using the simulator to keep track of the weather patterns. It is important that you pay attention to the wind patterns generated by the different pressure system. For reference, this is what each position means on the table. Describe where the hurricane lands and the wind patterns

Low and High Pressure:

Position 1	Position 2
Position 3	Position 4

Hurricane:

Position 1
Position 2

Hurricane Position	Low Pressure Position	High Pressure Position	What happened?
1	1	1	
1	1	2	
1	1	3	
1	1	4	
1	2	1	
1	2	2	
1	2	3	
1	2	4	
1	3	1	
1	3	2	
1	3	3	
1	3	4	
1	4	1	
1	4	2	
1	4	3	
1	4	4	
2	1	1	
2	1	2	
2	1	3	
2	1	4	
2	2	1	
2	2	2	

2	2	3	
2	2	4	
2	3	1	
2	3	2	
2	3	3	
2	3	4	
2	4	1	
2	4	2	
2	4	3	
2	4	4	

Tracking Tempests

Name:
Date:

Welcome back to NHC, candidate. Now that you know how a hurricane functions and what causes it to shift its path, it's time to start tracking.

First you'll need to understand the Saffir-Simpson Hurricane Wind Scale by reading this article: http://www.e-missions.net/HurricaneAlert/?cat=72&sid=2&pid=126&page=The%20Saffir-Simpson%20Hurricane%20Wind%20Scale

List the types of categories for a hurricane and what happens at each level.

Now it's time to look at how the NHC actually tracks hurricanes and become familiar with the terms:
http://www.e-missions.net/HurricaneAlert/?cat=72&sid=2&pid=89&page=Student%20Pages

Answer the questions on this webpage below:

1) What is your forecast if you use map #1?

2) What is your forecast if you use map #2?

3) Describe why your 2 forecasts were different.

One last thing is needed before you can start tracking hurricanes, some simple math and terminology to help with predicting where a storm will end up. You are allowed to use a calculator if your teacher permits it.
(Note, the following is taken directly from the Hurricane Alert website)

Converting wind speeds from knots to miles per hour.

Knots x 1.15 = miles per hour.

Example:

27 knots (kts) = ? miles per hour (mph)
27 x 1.15 = 31.05 miles per hour

Practice problems

1. 45 knots = _____ miles per hour

2. 67 kts = _____mph

3. 100 kts = _____mph

4. 135 kts = _____mph

Calculating the directional speed of the hurricane.

Speed = Distance ÷ Time

Speed = number of miles (from one advisory point to another)—provided on your practice data worksheet ÷ number of hours from one advisory to the next.

Example:
If the hurricane traveled 105 miles in 4 hours (from 8 am to 12 pm), then

105 ÷ 4 = 26.3 miles per hour

Practice problems

1. A hurricane traveled 200 miles in 6 hours. Speed = _____ miles per hour (mph)

2. A hurricane traveled 158 miles in 4 hours. Speed = _____ mph

3. A hurricane traveled 105 miles in 3 hours. Speed = _____mph

4. A hurricane traveled 120 miles in 2.5 hours. Speed = _____ mph

Calculate the Estimated Time of Arrival (ETA) to breakpoint cities.

A breakpoint city is an official location identified by the National Weather Service to be used when predicting hurricane impacts. (For your Hurricane Alert! mission, breakpoint cities are identified on your Hurricane Tracking Map by the Zone Predictors.)

To find a hurricane's ETA to a location, divide the distance from the hurricane to the location by the speed of the hurricane.

$$\text{ETA} = \frac{\text{distance to breakpoint area (in miles)}}{\text{speed of hurricane (miles/hour)}}$$

Example:
If a hurricane is 300 miles away from Miami and is traveling 60 miles an hour, it will reach Miami in (300 ÷ 60) 5 hours.

If it was traveling 100 miles an hour, it would reach Miami in (300 ÷ 100) 3 hours.

Practice Problems

1. A breakpoint city is 555 miles away from Hurricane Lucille traveling 68 miles per hour (mph). ETA = _____.

2. A breakpoint city is 124 miles away from Hurricane Bob traveling 54 miles per hour (mph). ETA = _____.

3. A breakpoint city is 379 miles away from Hurricane Edna traveling 75 miles per hour (mph). ETA = _____.

4. A breakpoint city is 283 miles away from Hurricane Frank traveling 78 miles per hour (mph). ETA = _____.

Are you ready to start tracking? Get out a Hurricane Tracking Map and a Student Data Worksheet (see Sources and Resources for both documents). You'll be following the Student Data Worksheet to practice classification and tracking. Your instructions start at the **Procedures** section of this website: http://www.e-missions.net/HurricaneAlert/?cat=72&sid=2&pid=112&page=Student%20Pages

It is time for an actual practice run before the big test comes in. Since you don't have access to Supercomputers that can calculate the complex prediction algorithms that NOAA uses before releasing weather data to the public, we'll have to go with the old fashioned method: Weather Stations.

Thanks to modern technology it's easy for a Weather Station out in the Caribbean to contact NOAA about a Tropical Depression heading their way. Specifically, the Weather Station sends out a Weather Advisory, with details about the storm. For purposes of this activity, you will have the time, the Latitude and Longitude (North and West), Air Pressure and the Internal Wind speed. Using this data, it is your team's job to determine:

1) What category the hurricane is (if it is at hurricane status at that point)
2) Directional speed and
3) Predict where it's going to hit.

Let your teacher know once you've completed the Student Tracking Worksheet to move on to the final test to see who makes it into NOAA as hurricane specialists.

Tracking Tempest Test

Below is a set of hurricane data recently reported from one of our weather stations. It is your job to fill out the Blank Hurricane Tracking Worksheet (see Sources and Resources) completely and then be prepared to present with your group the path of the hurricane (making it important to mark the Hurricane's path on the map) and where it may hit. If you need practice on how to fill the Blank Hurricane Tracking Worksheet, refer to the Hurricane Tracking Practice Worksheet (see Sources and Resources).

Advisory	Time	Latitude North	Longitude West	Air Pressure (mb)	Wind Speed (Knots)
1.00	Sept. 3, 6 AM	20.60	48.80	992.00	55.00
2.00	Sept. 3, 6 PM	21.20	51.10	979.00	75.00
3.00	Sept. 4, 6 PM	23.40	57.70	940.00	114.00
4.00	Sept. 6, 6 AM	22.40	66.40	964.00	100.00
5.00	Sept. 8, 6 AM	21.10	76.50	950.00	100.00
6.00	Sept. 10, 6 AM	23.40	84.60	964.00	69.00
7.00	Sept. 12, 6 AM	26.40	91.10	954.00	89.00
8.00	Sept. 13, 6 AM	29.10	94.50	951.00	94.00