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ABSTRACT

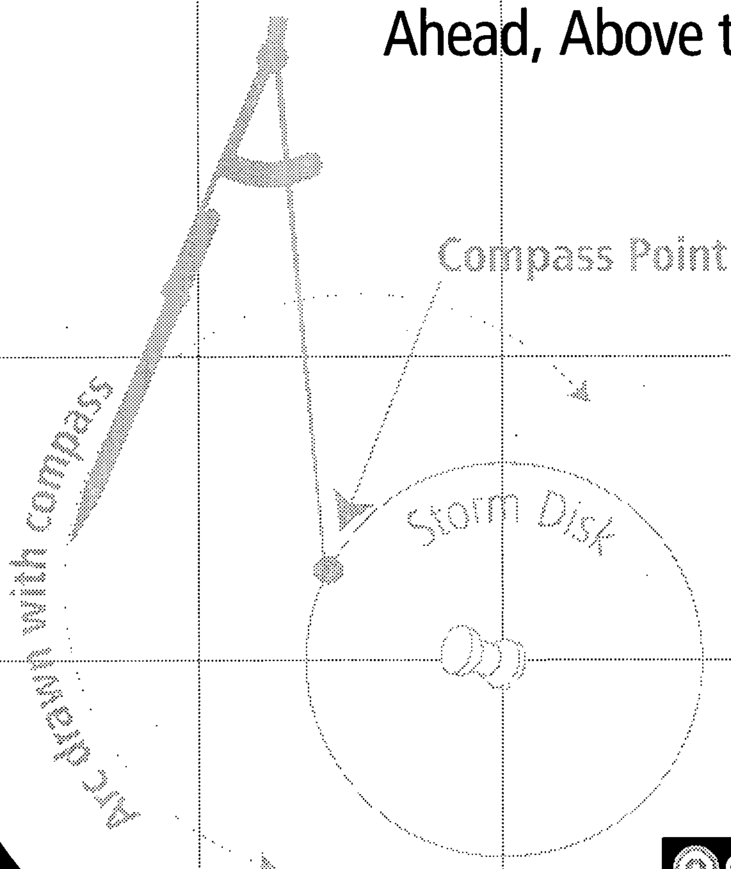
This teaching unit is designed to help students in grades 5 to 8 explore the concepts of data analysis and measurement in the context of meteorology. The units in the series have been developed to enhance and enrich mathematics, science, and technology education and to accommodate different teaching and learning styles. Each unit consists of background notes for the teacher, a list of teacher resources, and two activities, one of which is Web-based, complete with blackline masters. Also included are suggestions for extensions to the problems and their relationships to national mathematics, science, and technology standards. In this activity, students learn about hurricanes and how meteorologists, weather officers, and National Aeronautics and Space Administration (NASA) researchers use measurement and data analysis to predict severe weather such as hurricanes. (MM)

NASA CONNECT

Program 4 in the 2000-2001 Series

Data Analysis and Measurement:

Ahead, Above the Clouds



Educator's Guide	
Teachers & Students	Grades 5-8

Publication Number EG-2001-01-22-LaRC

PROGRAM OVERVIEW

SUMMARY AND OBJECTIVES

In *Data Analysis and Measurement: Ahead, Above the Clouds*, students will learn about hurricanes and how meteorologists, weather officers, and NASA researchers use measurement and data analysis to predict severe weather such as hurricanes. Students will also discover how the Geostationary Imaging Fourier Transform Spectrometer (GIFTS) will enable people to avoid the loss of life and property by warning them of approaching hazardous weather. Students will observe meteorologists interpreting graphs to predict hurricanes. By conducting classroom and on-line activities, students will make connections between NASA research and the mathematics, science, and technology they learn in their classroom.

INTERACTIVE ACTIVITIES

Questions are posed throughout the video by Norbert, the animated cohost of NASA CONNECT. These questions direct the instruction and encourage students to think about the concepts being presented. An icon appears in the video to suggest to teachers an appropriate place to pause the video and discuss the answers to the questions. Students record their answers on the Student Cue Cards (p. 23).

The Imperfect Storm, the hands-on classroom activity, is teacher-created and aligned with the national mathematics, science, technology, and geography standards. As a team of meteorologists, students will track a storm developing off the coast of Africa, predict the probability of landfall, and issue hurricane watches and warnings. Using measurement and data analysis, students will understand the complexity of hurricane forecasting.

The on-line activity, Hurricane Lab at Riverdeep EarthPulse Center, invites students to connect their scientific understanding of hurricanes with mathematical understanding of their behavior. Students will use SimPlayer visualization and simulation tools to study hurricane behavior and then predict their paths and development. The Hurricane Lab at EarthPulse Center is located in Norbert's lab at **http://connect.larc.nasa.gov/clouds/norbert/lab.html**

RESOURCES

Teacher and student resources (p. 25) support, enhance, and extend the NASA CONNECT program. Books, periodicals, and web sites provide teachers and students with background information and extensions. In addition to the resources listed in this lesson guide, the NASA CONNECT web site, **connect.larc.nasa.gov**, offers on-line resources for teachers, students, and parents. By connecting to Norbert's Lab, the NASA CONNECT "Lab Manager" offers assistance to teachers who would like to get the most out of the site.

THE CLASSROOM ACTIVITY

BACKGROUND

NASA Langley Research Center's Atmospheric Sciences Division, in conjunction with the U.S. Navy, is developing a new technology called a Geostationary Imaging Fourier Transform Spectrometer (GIFTS). GIFTS will give highly detailed information about the temperature, water vapor, and winds in the Earth's atmosphere. Radically improving predictions of severe weather conditions, GIFTS will also extend the range of global weather predictions and enable the monitoring and predicting of hazardous chemical pollutants affecting air quality. GIFTS will be able to monitor the Earth's atmosphere and provide scientists with a wealth of information. With the improved predictions of severe weather conditions, meteorologists around the world will be able to forecast hurricane formation and movement with more accuracy.

"The Imperfect Storm" is a game that will help students understand the complexity of hurricane forecasting. They will be given the coordinates for a storm, and as they plot positions, they will be predicting hurricane watches and warnings. Landfall will be calculated and conflicts will arise for the teams of student meteorologists. The winner of the game will be the team that has plotted the positions of the hurricane most accurately and has made correct decisions about the conflicts.

Hurricanes are the most powerful and destructive storms on Earth. The name hurricane came from a West Indian word for "big wind." However, as scientists have learned over the years, hurricanes are much more than big winds. To understand a hurricane, there are several basic components to weather that first must be understood.

AIR PRESSURE

Hurricanes are low-pressure systems that form over the Atlantic Ocean near Africa between June and November, with a peak in mid-August through October. The low-pressure system generally forms from a tropical wave moving from Africa over the warm Atlantic Ocean. As the warm, humid Atlantic air rises, it begins to circulate in a counterclockwise motion. As this air rises, it begins to condense, releasing the heat that fuels thunderstorms. Some of the rising air forms high clouds that can spread outwards for hundreds of miles. As the storm intensifies, some of the rising air converges toward the center of the storm and begins to sink, forming a cloud-free "eye." Heat, released by the condensation process, makes the warm air rise around the storm center. The descending air in the "eye" warms as the air becomes compressed as it moves downward into higher atmospheric pressure and causes the surface pressure of the storm to get lower and lower.

Pressure and wind speed have a negative correlation. The lower the pressure, the more intense the storm. Therefore, if pressure is dropping in the eye, the wind speeds will increase due to a greater difference in pressure between the storm center and its environment. If the pressure is increasing in the eye, the winds will decrease.

Air pressure is measured in **millibars** and is shown on a map with lines called **isobars**, which are drawn in a somewhat circular shape. Along each isobar, the pressure is the same. Around a low-pressure system, the lowest pressure would be in the center circle with increasing pressure going outward. Normal air pressure at the surface of the Earth is around 1,013 millibars compared with a hurricane's pressure of about 930 millibars. In a hurricane, air pressure is measured in the eye of the storm.

With GIFTS's new technology, scientists will be able to obtain wind data at multiple layers of the atmosphere. The present technology only allows wind readings at one level at a time.

WIND

Differences in air pressure are what create wind. As the warm air rises, it spirals outward due to the storms rotation and creates a low concentration of air molecules at the surface, causing the surrounding air to rush in to take its place. The rushing in of the surrounding air is the wind. The greater the difference between the pressure at the storm center and the pressure of the environment, the stronger and more forceful the winds.

With GIFTS's ability to view multiple layers in the cloud-free environment of the storm, meteorologists will be able to view the winds that steer the storm. Seeing the winds will give a more accurate forecast of the track of the hurricane and where it will come ashore.

HUMIDITY

Humidity is the number of water vapor molecules comprising the air. The amount of water vapor that air can hold depends on the temperature of the air. In warm air, the molecules have more space between them (low pressure); therefore, more water vapor can be contained. In cold air, the molecules are already very densely packed, and there is not much room for the addition of water vapor.

In a tropical depression, the storm is fed more and more water vapor from the warm ocean water. The storm draws its energy from the warm water that evaporates, moistening the air next to the surface. This moist air then rises, cools, and condenses, releasing heat and creating clouds. Eventually, the water droplets will grow large enough to fall, causing rain. The warmer the surface temperature of the ocean, the more water vapor will be fed to the storm.

With water vapor feeding a storm, it is important to be able to accurately measure it at all levels surrounding the hurricane. GIFTS will be able to observe the movement of the humid air in the cloudless region surrounding the hurricane. That observation will help scientists predict the strength of the storm, when it will intensify, and where it will go.

THE CYCLONIC STORM (HURRICANE)

A cyclone in the Northern Hemisphere will always turn in a counterclockwise motion. Due to this motion, as a hurricane approaches land, the "right" side of the storm, which is often the eastern/northeastern side of the storm, will have the most intense winds and heaviest rainfall. As the winds turn in the counterclockwise motion, moisture is picked up from the ocean and as the first bands of the storm hit land, a deluge of rain will fall. At this stage, the low-pressure system of the hurricane meets the higher pressure system on land, and the winds and weather will be the most violent. As the system continues to turn, most of the moisture will have fallen as rain. Therefore, the west/northwestern side of the storm will receive less rain and less intense weather.

If you break a hurricane into quadrants, the northeast quadrant will have the worst weather. More tornadoes are formed over land in this quadrant as the hurricane hits land. The winds are greater and more rain will fall; therefore, this is where the most damage will occur as a hurricane makes landfall. In many areas it is called the "dirty side" of the storm.

THE NAMING OF A HURRICANE (EXCERPT FROM NOAA)

Hurricanes are named because experience shows that the use of short, distinctive given names, in written as well as in spoken communication, is quicker, and less subject to error than the older, more cumbersome latitude-longitude identification method. For more information on the naming of hurricanes and to view the hurricane names for this year, visit: **http://www.fema.gov/kids/hunames.htm**

ZULU TIME

Zulu time is a universal time that conforms to the mean diurnal rotation of the Earth and serves as a basis of civil timekeeping. Universal time (UT1) is determined from observations of the stars, radio sources, and also from ranging observations of the Moon and artificial Earth satellites. Zulu time was formerly called Greenwich mean time. Governments and military primarily use it. For more information visit:
http://www.dtic.mil/doctrine/jel/doddict/data/u/06629.html

NATIONAL STANDARDS

MATHEMATICS (NCTM) STANDARDS

- Understand the meaning of operations and how they relate to each other.
- Use computational tools and strategies fluently and estimate appropriately.
- Understand various types of patterns and functional relationships.
- Use mathematical models and analyze change in both real and abstract contexts.
- Select and use different representational systems; include coordinate geometry and graph theory.
- Use visualization and spatial reasoning to solve problems both within and outside of mathematics.
- Understand attributes, units, and systems of measurement.
- Apply a variety of techniques, tools, and formulas for determining measurements.
- Pose questions and collect, organize, and represent data to answer those questions.
- Develop and evaluate inferences, predictions, and arguments that are based on data.
- Develop a disposition to formulate, represent, abstract, and generalize in situations within and outside mathematics.
- Monitor and reflect on students' mathematical thinking in solving problems.
- Organize and consolidate, through mathematical thinking, to communicate with others.
- Express mathematical ideas coherently and clearly to peers, teachers, and others.
- Recognize, use, and learn about mathematics in contexts outside of mathematics.
- Create and use representations to organize, record, and communicate mathematical ideas.
- Use representations to model and interpret physical, social, and mathematical phenomena.

SCIENCE (NSTA) STANDARDS

- Science as Inquiry
  Abilities necessary to do scientific inquiry
  Understandings about scientific inquiry
- Physical Science
  Motions and forces
  Transfer of energy
- Earth and Space Science
  Structure of Earth system
- Science and Technology
  Abilities of technological design
  Understandings about science and technology
- Science in Personal and Social Perspectives
  Natural hazards
  Risks and benefits
- History and Nature of Science Standards
  Nature of science

TECHNOLOGY (NETS) STANDARDS

- Understand the ethical, cultural, and social issues related to technology.
- Use technology tools to enhance learning, increase productivity, and promote creativity.
- Use technology to locate, evaluate, and collect information from a variety of sources.
- Use technology tools to process data and report results.
- Use technology resources for solving problems and making informed decisions.

GEOGRAPHY (NCSS) STANDARDS

- Understand how to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective.
- Understand how to analyze the spatial organization of people, places, and environments on the Earth's surface.
- Understand the physical processes that shape the patterns of Earth's surface.
- Understand how physical systems affect human systems.

INSTRUCTIONAL OBJECTIVES

The student will be able to

- plot points on a coordinate map by using a set of coordinates given.
- classify hurricanes according to NOAA (National Oceanic and Atmospheric Administration) guidelines.
- calculate speed of a storm by using formulas, scales, and a compass .
- calculate future distance of hurricane and tropical winds to issue watches and warnings by using measurement tools, formulas, and a scale.
- locate geographical locations using an atlas.
- make justifiable decisions for various crisis conflicts based on given information and student knowledge of weather and hurricanes.
- make predictions on hurricane landfall using mathematical probability.
- interpret and analyze data.

VOCABULARY

air mass - a large body of air that has the properties of the surface over which it is formed

air pressure - the force of gravity acting on the mass of air, pushing it downward and together, causing collisions between molecules and resulting in pressure

convection - the transfer of heat by actual movement of the heated material Meteorologists usually use "convection" to refer to up and down motions of air.

condensation - the process by which molecules of water vapor in the air become liquid water

eye - the low-pressure center (core) of a hurricane. Winds are normally calm and sometimes the sky is clear.

eye wall - the ring of thunderstorms that surrounds a storm's eye. The heaviest rain, strongest winds, and greatest turbulence are normally in the eye wall.

high pressure - an air mass with densely packed air molecules where cold air descends and rotates clockwise

hurricanes - large swirling low-pressure systems with winds of at least 75 mph that form over tropical oceans. Depending on the location of the storms, they are also called cyclones and typhoons.

hurricane watch - hurricane or tropical storm conditions expected within 36 hours

hurricane warning - hurricane or tropical storm conditions expected within 24 hours

jet stream - narrow wind belts occurring near the top of the troposphere where trade winds and polar easterlies meet prevailing westerlies. These winds help to steer weather patterns across the United States and the Atlantic Ocean.

low pressure - an area where warm air rises and rotates counterclockwise

millibar - a unit of air pressure

rain bands - the spiraling arms of a hurricane that extend outward from the storm and contain rain

steering currents - an average of the upper atmospheric winds that steer the hurricane in different directions

surface currents - wind patterns at the surface of the Earth

sustained wind speed - the highest wind speed a hurricane maintains, not including gusts

trade winds - steady winds about 15 degrees north and south of the equator, caused by cool, descending air

tropical depression - a storm with maximum sustained winds less than 39 mph

tropical disturbance - the earliest stage of a hurricane. An organized area of thunderstorms that forms in the tropics and persists for more than 24 hours, with winds less than 30 mph.

tropical storm - a storm with winds between 39 and 74 mph

tropical wave - a kink or bend in the normally straight flow of surface air in the tropics, which forms a low-pressure trough

PREPARING FOR THE ACTIVITY

MATERIALS (PER STUDENT GROUP)

Student Directions Sheet (pp. 12-14)
Hurricane Tracking Map Game board (4 pieces, included in packet)
glue or tape
7 different **colored markers or colored pencils**
Student Data Chart (p. 16)
Conflict Chart: Student Answer Sheet (p. 19)
envelope with tropical storm and hurricane disks (envelope provided by teacher)
compass
calculator
Appendix B: Average September Hurricane Tracking Chart (p. 22)
atlas
cardboard

MATERIALS (FOR TEACHER)

Student Directions Sheet (pp. 12-14)
thermal transparencies
permanent **markers** (two different colors)
scissors
one **envelope** for each group
Teacher Data Chart (p. 15)
Conflicts (p. 17)
Conflict Chart: Teacher Answer Key (p. 18)
Tropical Storm and Hurricane Disks pattern (p. 20)
Appendix A: Storm Track Answer Key enlarged to 125% (p. 21)

TIME

Teacher preparation	30 min
Student construction of game board	15 min
Playing the game	90 min

ADVANCE PREPARATION

1. Copy the Tropical Storm and Hurricane Disks (p. 20) onto a thermal transparency for each team.
2. Use the permanent markers to outline the inner edge of all tropical storm disks in one color and all hurricane disks in another color.
3. Use a pushpin to puncture a hole at the center point on each disk.
4. Cut out each set of disks and place them in an envelope labeled "disks."
5. Enlarge Appendix A: Storm Track Answer Key (p. 21) 125%. Copy onto a transparency to use as a key to easily check students' progress throughout the game.
6. Organize teams. Each team consists of three members: a recorder, a plotter, and a calculator. At the end of each level, you may wish to have students switch jobs.
7. Copy the following for each team:
   Student Directions Sheet (p. 12)
   Hurricane Tracking Map Game board (included in packet)
   Student Data Chart (p. 16)
   Conflict Chart: Student Answer Sheet (p. 19)
   Appendix B: Average September Hurricane Tracking Chart (p. 22)

8. Optional: Record the data points and/or conflicts you will read to students onto an audio tape and add sound effects. This way you can have "bulletins" giving the updates for storm information and the conflicts.

NOTE: Be sure that all students have experience working with a compass. Have students practice using the compass to measure distance on a mileage scale.

Elapsed time is also an important component of the game. It is recommended that the students have experience with calculating elapsed time. You will also need to explain Zulu time (see background information, p. 4).

FOCUS QUESTIONS

What is a hurricane?
Why is a hurricane a very dangerous storm?
What areas of the country are affected by hurricanes?
Why is storm tracking an important component of weather forecasting?

THE ACTIVITY

STEP I: GAME SETUP

A. Students begin by organizing their materials.

NOTE: Use Student Directions Sheet (p. 12) for detailed instructions.

B. Students construct the Hurricane Tracking Map game board.

C. Have students place cardboard under the game board.

D. Students categorize the storm disks found in the envelope you provided.

E. After students have made the game board, they should create a key on the Saffir-Simpson Scale on their game board.

STEP 2: BEGINNING THE GAME

A. Read or post the following information (data point #1) to begin the game: "Right off the coast of Africa, there is a tropical wave that is forming a low-pressure system. The National Oceanic and Atmospheric Administration (NOAA) has reported winds of 30 mph with a pressure of 1100 millibars and falling. The coordinates are 16 North and 35 West as of 06 Zulu time on September 6. NOAA will continue to keep a watch on this storm."

B. Students record information for data point #1 on their Student Data Chart (p. 16).

C. Students look at the wind speed and the Saffir-Simpson Scale to classify the storm. To help students start the game, the first storm has already been classified as a tropical depression on the Student Data Chart. Discuss why this is a tropical depression *(winds under 35 mph)* and have students record on their Student Directions Sheet (p. 12).

D. Students plot the coordinate on their game board and label the point TD with the appropriate color from the Saffir-Simpson Scale.

E. Repeat process for data point #2, reading ONLY date, time, latitude, longitude, wind speed, and pressure from the Teacher Data Chart (p. 15). Students record information.

STEP 3: PLAYING THE GAME - LEVEL I

A. From the Teacher Data Chart, read or post information for data point #3.

B. Students record the information on their data chart and classify the storm appropriately.

C. Students plot the coordinate on the game board and label the data point with the correct storm abbreviation (TD, TS, H1, H2, H3, H4, or H5).

D. Students use a compass to measure the distance that the storm has traveled between the last two points labeled. Then, they transfer the compass to the mileage scale on the game board to determine the miles traveled. Students record mileage on the Student Data Chart (p. 16).

E. Students calculate elapsed time by finding the difference between the current and previous time (ex. 18 Zulu - 6 Zulu = 12 hours elapsed). Use formula 1 (speed = distance/elapsed time) to calculate the speed at which the storm is moving. Round to the nearest whole number and record speed on the Student Data Chart.

F. Students use formula 2 (watch=speed X 36) to calculate the distance that the storm will travel in 36 hours and record the answer on the Student Data Chart.

G. Students use formula 3 (warning=speed X 24) board to calculate the distance the storm will travel in 24 hours and record the answer on the Student Data Chart.

H. Students find the disk corresponding to the storm's classification. For example, data point #3 is a tropical storm; therefore, the students should use the disk labeled TS.

I. Students align the center point of the disk with the coordinate point they've just labeled on the game board. Use a pushpin to hold the disk in place.

ISSUE WATCHES AND WARNINGS

J. Using the mileage scale, students adjust the compass for the distance in miles that they predicted the storm will travel in 24 hours (see figure 2).

K. Students will place the compass on the edge of the disk in the direction they predict the storm is moving. Without readjusting the compass, students lightly draw an arc to see where landfall might occur (see figure 3).

NOTE: Guide students to determine where to place their compasses. The compass point should be placed on the edge of the disk in the direction the storm is moving. Most storms do not move backwards at this stage of their development. Have students refer to Appendix B: Average September Hurricane Tracking Chart (p. 22) to give them a better concept of where and how hurricanes travel.

L. Using an atlas, students identify land areas at risk and estimate and predict warnings based on the arc drawn.

NOTE: The area between the edge of the disk and the arc is the area that will be receiving tropical storm winds within the next 24 hours if the storm continues at its current speed.

M. Students record their predictions on the Student Data Chart.

N. Using the distance the storm traveled in 36 hours, students adjust the compass, draw a new arc, and issue watches.

ANNOUNCE CONFLICTS AND DISCUSS

O. Read or post conflict (p. 17).

NOTE: Not all data points have conflicts. See conflicts to determine when to read the scenarios. If there is no conflict, read the next data point.

Figure 1 appears only in student directions.

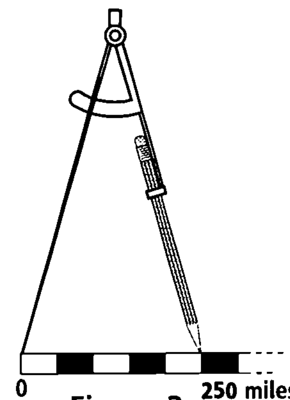


Figure 2

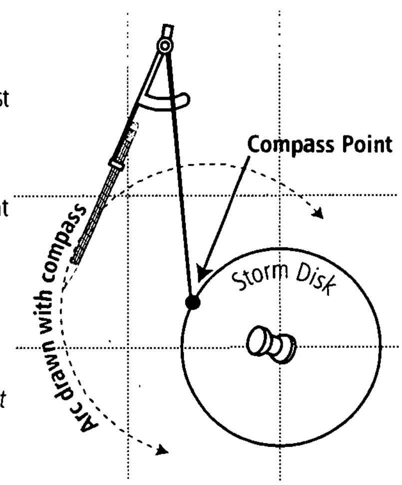


Figure 3

P. Students find the geographical location of the conflict, determine what action, if any, should be taken, and record the decision and action on the Conflict Chart: Student Answer Sheet (p. 19).

Q. Discuss the correct answers for the Conflict and award points as indicated on Conflict Chart: Teacher Answer Key (p. 18) Students record their points on the Conflict Chart: Student Answer Sheet (p. 19).

NOTE

NOTE: You may want to initial points awarded.

AWARDING POINTS FOR DATA CHARTS AND GAME BOARD

R. At the end of the level, use transparency of Appendix A: Storm Track Answer Key (p. 21) to check students' coordinates, labels, and data sheet to make sure they are on track. Use scoring charts to determine points and place awarded points on the score card located at the top of each group's game board.

STEP 4

STEP 4: PLAYING THE GAME LEVEL II - IV

A. Repeat step 3, A-N for data points #4 - #5.

B. Read data point #6 and have students record data, plot coordinate, label point, determine distance storm traveled, calculate speed storm traveled, and distance storm travels in 36 hours and 24 hours.

C. When the storm becomes a hurricane, students will need to use two disks instead of one because the tropical storm force winds extend farther out than the hurricane force winds. Be sure that as the hurricane changes category, students use the appropriate tropical storm disks.

D. Students use the Disk Combinations chart to determine the appropriate disks. Students align center points of the two disks and place a pushpin through the center of the disks and the coordinate on the game board (see figure 4).

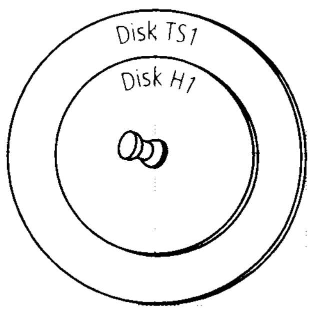


Figure 4

E. From this point on, make sure students always place the compass point on the edge of the hurricane disk (the smaller disk) when drawing arcs. Students continue to issue hurricane watches and warnings following the instructions in step 3.

Scoring (Levels I - III)

Each team will receive

5 points for each coordinate plotted correctly.

5 points for each correct watch issued.

5 points for each correct warning issued.

10 points for each conflict resolved correctly.

The team with the highest point value will win the game!

Scoring (Level IV)

25 points for correct U.S. landfall prediction by data point number 14.

15 points for correct U.S. landfall prediction by data point number 15.

10 points for correct U.S. landfall prediction by data point number 17.

Disk Combinations

Category I Hurricane:
TS1(Tropical Storm Status) and H1(Hurricane Category I)

Category II Hurricane:
TS2(Tropical Storm Status) and H2(Hurricane Category II)

Category III Hurricane:
TS3(Tropical Storm Status) and H3(Hurricane Category III)

Category IV Hurricane:
TS4(Tropical Storm Status) and H4(Hurricane Category IV)

Category V Hurricane:
TS5(Tropical Storm Status) and H5(Hurricane Category V)

NOTE

NOTE: In a real storm, tropical storm watches and warnings would continue to be issued. However, after data point #5, students will concentrate on just the hurricane watches and warnings.

F. Continue playing until the data chart and conflict chart have been completed. Award points as indicated in step 3 and total the points from the game board score card and the conflict chart. The team with the most points wins!

STEP 4

STEP 5: CONCLUSION/DISCUSSION

A. Overall, the damage by hurricanes has been increasing since the1960s. What are some possible factors?

(Possible answers: More people live in coastal communities, causing an increase in property damage. More expensive homes are being built at the coast. Storms are occurring more often or with more force.)

B. The top ten hurricanes, which caused the most deaths, occurred before 1960. What possible factors contribute to fewer lives being lost today?

(Possible answers: Technological advances and meteorologists' ability to predict and track storms give people advanced warning and time to evacuate; improved and increased communication ability allows warnings to reach more peopl;, better road systems provide more people the means to evacuate; better rescue efforts and technology allow rescue workers to save more lives, and deaths can be prevented by improvements in building design.)

C. How difficult is it to track and predict hurricanes?

(Possible answers: It is very difficult to predict hurricanes accurately. There are many variables involved in predicting the track of a hurricane. With our current technology, we are unable to see all the variables in advance. With the GIFTS satellite, this technology will be greatly improved and will, in turn, improve hurricane tracking.)

EXTENSIONS

A. Using the Internet or an almanac to find information, have the students plot the locations where hurricanes have made landfall within the past 5 years on the Hurricane Tracking Map game board. Make a bar graph showing the data between states versus hurricane landfalls. Do not include states that have had no landfalls.

B. Using the above information, have the students calculate the percentage of hurricanes making landfall in each Atlantic coast state.

C. Compare and contrast hurricanes (Atlantic) and typhoons (Pacific). Compare number of landfalls, storm strength, property damage, and loss of life.

D. Research other natural disasters such as tornadoes, floods, and earthquakes. Compare the amount of damage done by each category.

STUDENT WORKSHEETS

STUDENT DIRECTIONS SHEET

Names______________________________
____

Objective: As a team of meteorologists, it is your job to track the storm brewing off the coast of Africa. You will need to predict the probability of landfall and issue watches and warnings. The team with the most accurate predictions will be the heroes of the day as well as the winners of the game.

Materials (per group)

Hurricane Tracking Map game board (4 pieces)
glue or tape
7 different colored **markers or pencils**
Student Data Chart
Conflict Chart: Student Answer Sheet
envelope with tropical storm and hurricane disks
compass and/or ruler
calculator
Appendix B: Average September Hurricane Tracking Chart
atlas
cardboard

STEP 1

STEP 1: GAME SETUP

A. Gather all materials.

B. Construct the Hurricane Tracking Map game board by taping or glueing the four sheets of the grid map together, matching the latitude and longitude lines. You may have to cut off a small portion of the overlapping edges of the game board to line up the lines (see figure 1). If you use tape, be sure that the tape is on the back of the map.

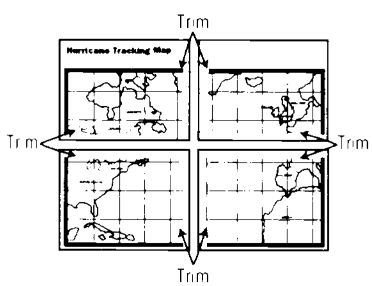


Figure 1

C. Place cardboard under the game board.

D. Categorize the disks located in a marked envelope (provided) by hurricane (H1 to H5), and tropical storm (TS, TS1 to TS5).

NOTE

Note: There will not be a disk for tropical depression (TD).

E. Create a key on the game board by assigning a different color for each storm category: Tropical depression (TD), Tropical Storm (TS), Hurricane Category I (H1), II (H2), III (H3), IV (H4), and V (H5). Color in the rectangle on the game board for the corresponding color chosen.

STEP 2

STEP 2: BEGINNING THE GAME

A. Read or listen to the storm information given by the teacher for data point #1.

B. On the Student Data Chart, record date, time, latitude, longitude, wind speed, and pressure of the storm for data point #1.

C. Look at the wind speed. Use the Saffir-Simpson Scale on the game board to determine the storm's classification and record in the cateogry column on the Student Data Chart. To help you start the game, the first storm has been classified for you as a tropical depression. Why is this storm a tropical depression?

____

____

D. Plot the coordinate on the game board using the appropriate color from the Saffir-Simpson Scale key. Label this data point according to its category (TD, TS, H1, H2, H3, H4, or H5).

E. Read or listen to data point #2, record information, classify, plot, and label storm as you did for data point #1.

STEP 3

STEP 3: PLAYING THE GAME - LEVEL I

A. Read or listen to data point #3.

B. Record date, time, latitude, longitude, wind speed, and pressure of the storm on the Student Data Chart.

C. Plot the coordinate using the color assigned on the Saffir-Simpson Scale key and label with the appropriate abbreviation (TD, TS, H1, H2, H3, H4, or H5).

D. Use a compass to measure the distance that the storm has traveled between the last two points labeled. Then, transfer the compass to the mileage scale on the game board (located in bottom left corner) to determine the miles traveled. Record mileage under "Distance Storm Traveled" on Student Data Chart.

E. Calculate elapsed time by finding the difference between current and previous time. Use Formula 1 (speed = distance/elapsed time) to calculate the speed at which the storm is moving. Round to the nearest whole number and record on the Student Data Chart under the column labeled "Speed Storm Traveled."

F. Use Formula 2 (watch = speed X 36) to calculate the distance that the storm will travel in 36 hours and record the answer on the Student Data Chart under the column labeled "Distance Storm Travels in 36 hours."

G. Use Formula 3 (warning = speed X 24) located at the top of the game board to calculate the distance the storm will travel in 24 hours and record the answer on the Student Data Chart under the column labeled "Distance Storm Travels in 24 hours."

H. Find the disk that represents the storm's classification.

I. Place the center point of the disk on top of the coordinate point you just labeled on the game board. Use a pushpin to hold the disk in place.

ISSUE WATCHES AND WARNINGS

J. Find the distance in miles you predicted the storm will travel in 24 hours. Use the mileage scale on the game board and adjust the compass for that distance. See figure 2.

K. Place the compass on the edge of the disk in the direction you predict the storm is moving (see Appendix B). Without readjusting the compass, lightly draw an arc to see where landfall might occur (see figure 3).

L. Use an atlas to identify land areas at risk. Estimate and predict warnings based on the arc you drew.

NOTE

NOTE: The area between the edge of the disk and the arc is the area that will be receiving tropical storm winds within the next 24 hours if the storm continues at its current speed.

M. Record your prediction on the Student Data Chart under the column labeled "Watches and Warnings."

N. Adjust the compass for the distance in miles that you predict the storm will travel in 36 hours, place your compass on the disk edge, draw a new arc, and issue watches.

CONFLICTS

O. Listen to the conflict read aloud by your teacher.

P. Find the geographical location of the conflict, determine what action, if any, should be taken and record your decision and action taken on the conflict Chart: Student Answer Sheet.

Q. Discuss the correct answers for the conflict and points will be awarded. Record your points on the Conflict Chart: Student Answer Sheet.

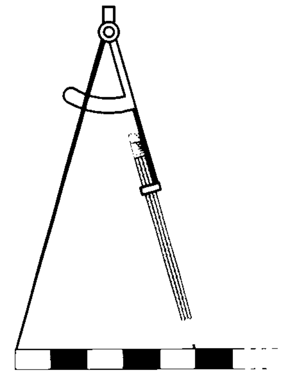


Figure 2

(also shown on p. 9)

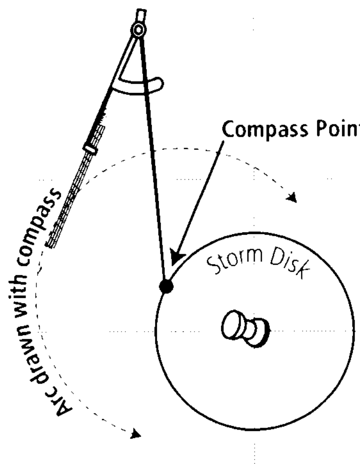


Figure 3

(also shown on p. 9)

Scoring (Levels I - III)

Each team will receive

5 points for each coordinate plotted correctly.

5 points for each correct watch issued.

5 points for each correct warning issued.

10 points for each conflict resolved correctly.

The team with the highest point value will win the game!

Scoring (Level IV)

25 points for correct U.S. landfall prediction by data point number 14.

15 points for correct U.S. landfall prediction by data point number 15.

10 points for correct U.S. landfall prediction by data point number 17.

CAUTION

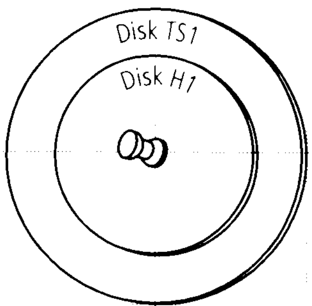


Figure 4
(also shown on p. 11)

Disk Combinations

Category I Hurricane:
TS1(Tropical Storm Status) and H1(Hurricane Category I)

Category II Hurricane:
TS2(Tropical Storm Status) and H2(Hurricane Category II)

Category III Hurricane:
TS3(Tropical Storm Status) and H3(Hurricane Category III)

Category IV Hurricane:
TS4(Tropical Storm Status) and H4(Hurricane Category IV)

Category V Hurricane:
TS5(Tropical Storm Status) and H5(Hurricane Category V)

AWARDING POINTS FOR DATA CHART AND GAME BOARD

R. At the end of the level, the teacher will award points for correct coordinates, labels, and data sheet information and will record on the scorecard located at the top of your game board. Make sure you have followed directions carefully.

STEP 4: PLAYING THE GAME - LEVEL II - IV

A. Data points #4 and #5 will be given by your teacher. Repeat step 3, B - N.

B. Listen for data point #6 to be given by your teacher and record data, plot coordinate, label point, determine distance storm traveled, calculate speed storm traveled, distance storm traveled in 36 and 24 hours, and record on data chart.

C. When the storm becomes a hurricane, you will need to use two disks instead of one because the tropical storm force winds extend farther out than the hurricane force winds. The disks marked HI, H2, H3, H4, and H5 will indicate the area of the hurricane where there are sustained hurricane force winds. The disks labeled TS1, TS2, TS3, TS4, and TS5 will indicate the area of sustained tropical storm winds. Be sure that as the hurricane changes category, you use the appropriate tropical storm disks.

D. Use the Disk Combinations Chart to determine the appropriate disks. Align center points of the two disks. Place a pushpin through the center of the disks and the coordinate on the game board (see figure 4).

E. From this point on, always continue to place the compass point on the edge of the hurricane disk (the smaller disk) when drawing arcs. Continue to issue hurricane watches and warnings (see step 3, J - R).

NOTE

NOTE: In a real storm, tropical storm watches and warnings would continue to be issued; however, after data point #5, you will concentrate on just the hurricane watches and warnings.

F. Continue playing until your data chart and conflict chart have been completed. Your teacher will award points and total the points from the game board score card and the conflict chart. The team with the most points wins.

STEP 5: CONCLUSION

1. Overall, the damage by hurricanes has been increasing since the1960s. What are some possible factors?____________________

2. The top ten hurricanes, which caused the most deaths, occurred before 1960. What possible factors contribute to fewer lives being lost today?__________

3. How difficult is it to track and predict hurricanes?____________________

TEACHER DATA CHART

	Point	Date	Zulu Time	Latitude	Longitude	Winds Speed (mph)	Pressure (mb)	Category	Distance Storm Traveled	Speed Storm Traveled	Distance Storm Trav. in 36 hours	Distance Storm Trav. In 24 hours	Watches (36 hours) Warnings (24 hours) Accept Reasonable Answers.
	#1	9/6	06 Zulu	16 N	35 W	30	1100	TD					No data needed
LEVEL I	#2	9/8	18 Zulu	16 N	51 W	45	1000	TS					No data needed
	#3 Conflict	9/9	06 Zulu	17 N	54 W	45	1003	TS	200	17	612	408	Lesser Antilles Puerto Rico
	#4	9/9	18 Zulu	18 N	56 W	60	996	TS	150	13	468	312	Lesser Antilles Puerto Rico
	#5	9/10	06 Zulu	19 N	58 W	60	990	TS	150	13	468	312	Lesser Antilles, Puerto Rico None
LEVEL II	#6 Conflict	9/10	18 Zulu	20 N	60 W	75	975	I	100	8	288	192	Northern Lesser Antilles East Coast of Puerto Rico
	#7 Conflict	9/11	06 Zulu	21 N	61 W	100	963	II	150	13	468	312	Northern Lesser Antilles, Puerto Rico Santo Domingo
	#8	9/11	18 Zulu	22 N	63 W	100	966	II	150	13	468	312	Virgin Islands, Puerto Rico Dominican Republic
	#9 Conflict	9/12	06 Zulu	23 N	65 W	100	960	II	150	13	468	312	None Dominican Republic, Haiti, Great Inagua
	#10 CC Conflict	9/12	18 Zulu	23 N	67 W	132	940	IV	125	10	360	240	Northern Dominican Republic Bahamas, Eastern Cuba, Haiti, Great Inagua
	#11	9/13	06 Zulu	24 N	70 W	140	922	IV	200	17	612	408	E Cuba, Bahamas, Great Inagua, Haiti, Dominican Republic Western Cuba, S FL Coast
LEVEL III	#12 Conflict	9/13	18 Zulu	24 N	73 W	140	923	IV	200	17	612	408	Cuba , Bahamas, Key West to Cape Canaveral Cape Canaveral to SE GA
	#13	9/14	06 Zulu	25 N	75 W	115	927	III	150	13	468	312	Bahamas, Cuba, FL Keys to Central FL Central FL to SE GA
	#14 Conflict	9/14	18 Zulu	26 N	77 W	115	930	III	150	13	468	312	N Cuba, Bahamas, FL Keys to Northern FL Southern GA to NE SC
	#15	9/15	06 Zulu	28 N	79 W	112	935	III	200	17	612	408	N Bahamas, FL Keys to Wilmington, NC Wilmington, NC to Norfolk, VA
	#16 Conflict	9/15	18 Zulu	31 N	79 W	100	947	II	200	17	612	408	Central FL to Norfolk, VA Norfolk, Southern NJ
	#17	9/16	00 Zulu	32 N	79 W	100	950	II	100	17	612	600	N FL to Norfolk, VA Norfolk, VA to Atlantic City, NJ
LEVEL IV	#18	9/16	06 Zulu	34 N	78 W	100	956	II	150	25	900	696	Landfall occurs 50 miles SW of Wilmington, NC S SC to Atlantic City, NJ (warning) Atlantic City, NJ to Boston, MA (watch)
	#19	9/16	12 Zulu	36 N	77 W	75	967	I	175	29	1,044	792	S NC to Atlantic City, NJ Atlantic City, NJ to Boston, MA
	#20 Conflict	9/16	18 Zulu	38 N	75 W	60	974	TS	200	33	1,188	800	TS warning-Cape Hatteras, NC to Boston, MA TS Watch-Boston, MA to Nova Scotia

STUDENT DATA CHART

Point	Date	Zulu Time	Latitude	Longitude	Winds Speed (mph)	Pressure (mb)	Category	Distance Storm Traveled	Speed Storm Traveled	Distance Storm Trav. in 36 hours	Distance Storm Trav. In 24 hours	Watches (36 hours) Warnings (24 hours)
#1							TD					
#2												
#3 Conflict												
#4												
#5												
#6 Conflict												
#7 Conflict												
#8												
#9 Conflict												
#10 Conflict												
#11												
#12 Conflict												
#13												
#14 Conflict												
#15												
#16 Conflict												
#17												
#18												
#19												
#20 Conflict												

LEVEL 1 LEVEL 2 LEVEL 3 LEVEL 4

CONFLICTS

DATA POINT 3	Cruise ship steaming at 15 mph is leaving Nassau and heading towards Miami.
DATA POINT 6	Today a cruise ship is leaving Antigua and heading toward Puerto Rico. It will be steaming at 25 mph.
DATA POINT 7	Newlywed couple from Houston, TX are leaving today on a 4-hour direct flight from Houston to St. Lucia. Should they cancel their trip?
DATA POINT 9	Small single engine plane is flying at 130 mph with one hour of fuel left. It is off the coast of Antigua and needs to land immediately. What should the pilot do?
DATA POINT 10	Navy needs to conduct exercises today off the coast of Vieques, Puerto Rico.
DATA POINT 12	Cuban refugee boats spotted 50 miles south of Key West, FL heading towards Key West at 3 mph.
DATA POINT 14	A fishing boat is dead in the water 100 miles southwest of the coast of Charleston, SC. It will take two days for the captain to repair the engine himself. It will take the Coast Guard at least 10 hours to reach the boat and tow it back.
DATA POINT 16	A family from California is leaving today on a direct 5-hour flight to vacation at Disney World in Orlando, FL.
DATA POINT 20	A Concorde flight left England for Kennedy International Airport and is 400 miles east of its destination.

NOTE

Read or post after indicated data points.

CONFLICT CHART: TEACHER ANSWER KEY

Conflicts	Resolution	Points
Point 3	Full Steam ahead!	10
Point 6	A. Stay in Port. B. Steam to Puerto Rico. **C. Head south to Port-of-Spain.**	10
Point 7	Cancel the honeymoon trip.	10
Point 9	The storm will not affect the landing of the plane.	10
Point 10	**A. Cancel the exercises.** B. Conduct the exercises. C. Delay the exercise for 2 days.	10
Point 12	A. Head the boat back to Cuba. **B. Send the Coast Guard to rescue the refugees.** C. No danger, they can continue their trip.	10
Point 14	A. Stay and repair the boat. B. Call the Coast Guard to help tow the boat. **C. Call the Coast Guard to send helicopter and abandon ship.**	10
Point 16	A. Stay home. B. Leave as scheduled. **C. Delay trip by 3 days.**	10
Point 20	A. Land at Kennedy International Airport. **B. Turn back to England.**	10

(Correct answer is in bold.)

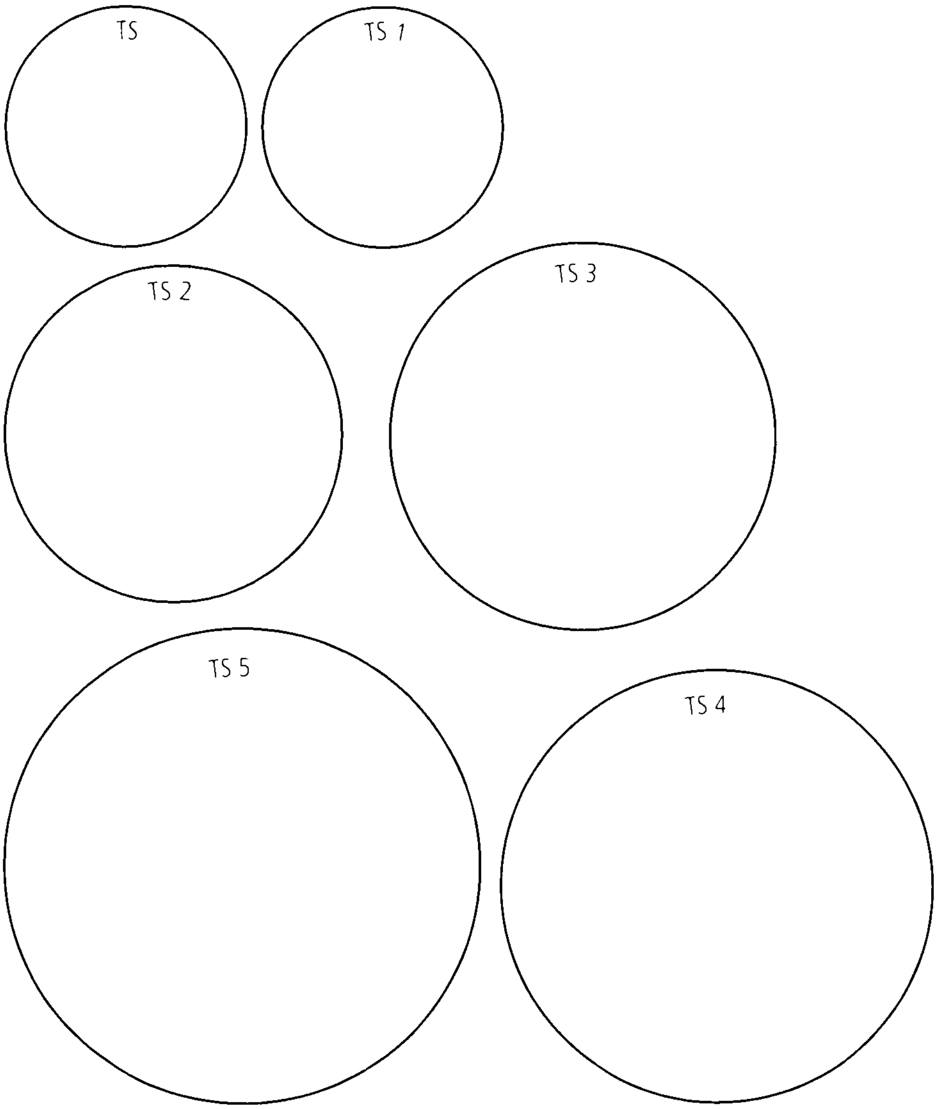
CONFLICT CHART: STUDENT ANSWER SHEET

Your teacher will read the conflicts after each data point listed. Write in or circle the correct resolution.

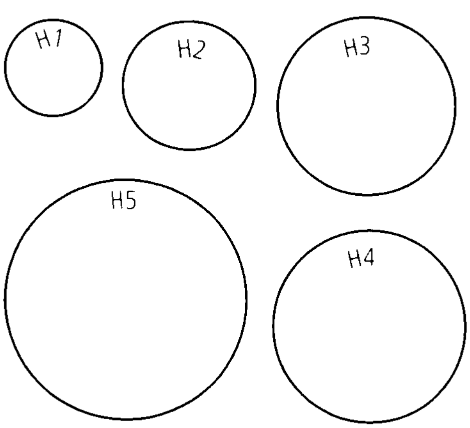
Conflicts	Resolution	Points
Point 3		
Point 6	A. Stay in Port. B. Steam to Puerto Rico. C. Head south to Port-of-Spain.	
Point 7		
Point 9		
Point 10	A. Cancel the exercises. B. Conduct the exercises. C. Delay the exercise for 2 days.	
Point 12	A. Head the boat back to Cuba. B. Send the Coast Guard to rescue the refugees. C. No danger, they can continue their trip.	
Point 14	A. Stay and repair the boat. B. Call the Coast Guard to help tow the boat. C. Call the Coast Guard to send helicopter and abandon ship.	
Point 16	A. Stay home. B. Leave as scheduled. C. Delay trip by 3 days.	
Point 20	A. Land at Kennedy International Airport. B. Turn back to England.	

TROPICAL STORM AND HURRICANE DISKS

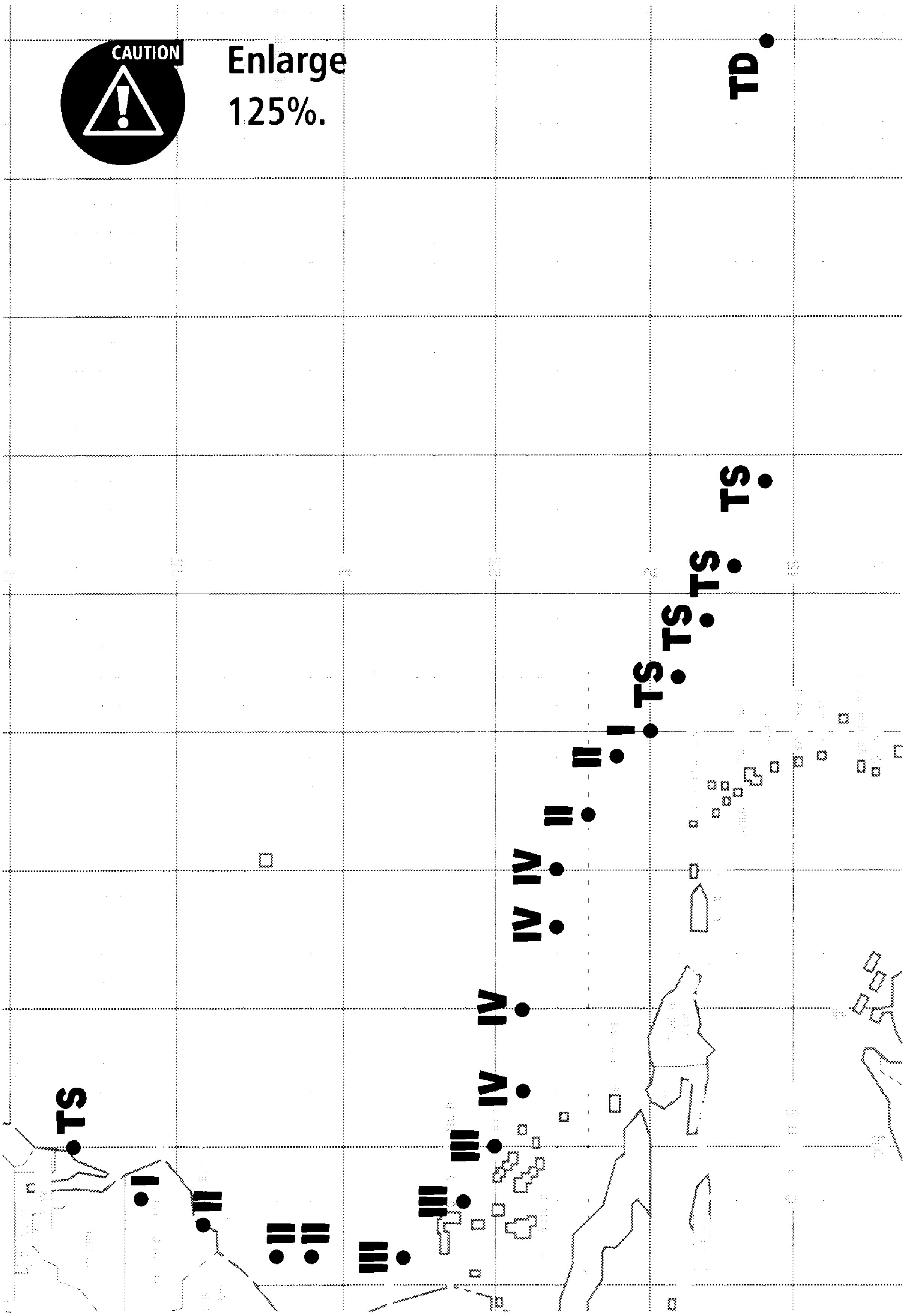
Tropical Storm Disks (Envelope provided by teacher.)



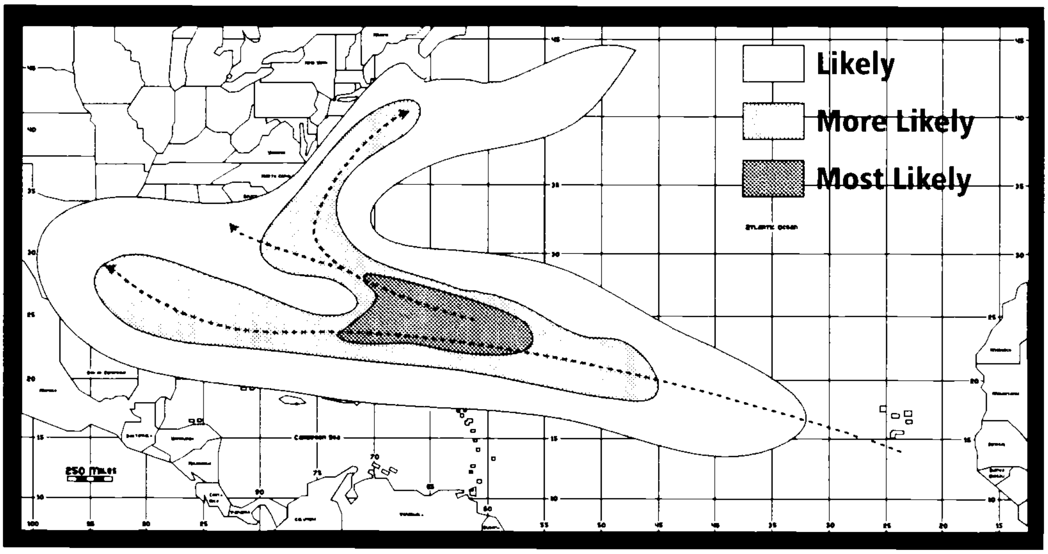
Hurricane Disks

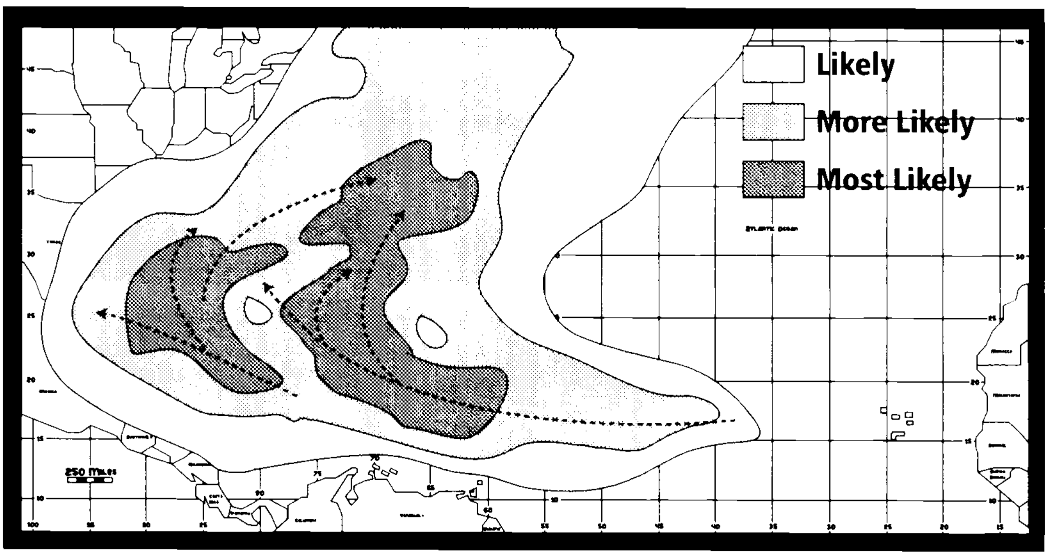


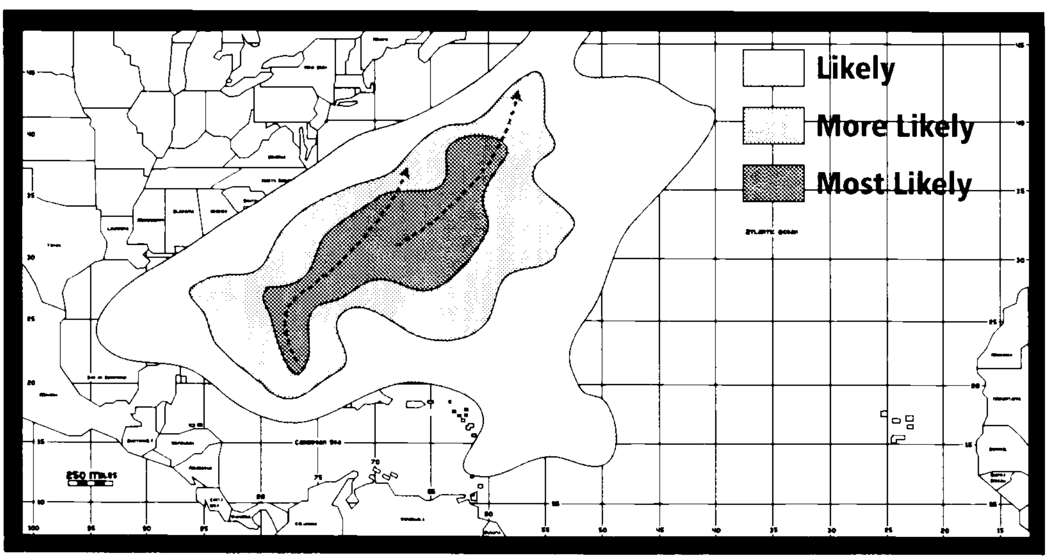
APPENDIX A: STORM TRACK ANSWER KEY



APPENDIX B: AVERAGE SEPTEMBER HURRICANE TRACKING CHART







STUDENT CUE CARDS

Major Valerie Hendry, Hurricane Hunters

1. Describe the instruments the Hurricane Hunters use to collect data on a hurricane. ______________________

2. What symbol is used to describe the flight pattern? ______________________

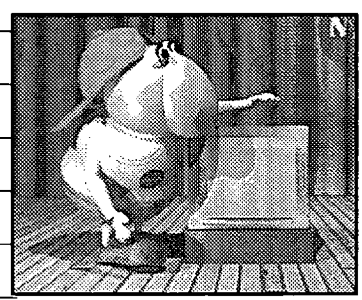
3. Which of the 4 variables shown in the graph is constantly increasing? ______________________

Dr. Bill L. Smith, NASA Langley Research Center

1. How will GIFTS provide a more complete picture of the Earth's atmosphere? ______________________

2. How does remote sensing work? ______________________

3. What does the information collected about the water vapor tell us about a storm? ______________________



THE WEB ACTIVITY

THE ACTIVITY

The Hurricane Lab is part of the Riverdeep EarthPulse Center, an on-line scientific research center for studying information about and gaining understanding of the major physical events that affect our changing Earth. It has been designed to fit well with the middle school Earth and Atmospheric Science curriculum, but it can be used and enjoyed by students of all ages. The Hurricane Lab at EarthPulse Center is located in Norbert's lab at **http://connect.larc.nasa.gov/clouds/norbert/lab.html**

NATIONAL STANDARDS

TECHNOLOGY (NETS) STANDARDS

- Develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity.
- Use technology tools to enhance learning, increase productivity, and promote creativity.

SCIENCE (NSTA) STANDARDS

- Motions and forces
- Transfer of energy
- Abilities of technological design
- Energy in the Earth system
- Natural hazards

MATHEMATICS (NCTM) STANDARDS

- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.
- Select and use appropriate statistical methods to analyze data.
- Develop and evaluate inferences and predictions that are based on data.
- Specify locations and describe spatial relationships using coordinate geometry and other representational systems.
- Use visualization, spatial reasoning, and geometric modeling to solve problems.
- Create and use representations to organize, record, and communicate mathematical ideas.
- Use representations to model and interpret physical, social, and mathematical phenomena.
- Recognize and apply mathematics in contexts outside of mathematics.

INSTRUCTIONAL OBJECTIVES

In the Hurricane Lab at EarthPulse Center, students will

- connect their scientific understandings of hurricanes with mathematical understandings of their behaviors.
- represent information in different ways and, conversely, understand different forms of representation.
- read and interpret static and dynamic displays of quantitative information.
- make inferences from available data.
- determine rate of speed.
- determine rate of speed from information about distance and time that is available.
- determine internal wind speed from information about intensity that is available.
- determine the nature of the relationship between pressure and wind speed.
- find and explore patterns and relationships.
- determine if there is any relationship between a hurricane's speed and its intensity.
- determine if there is any relationship and, if so, what kind, by graphing wind speed and pressure over time.
- make predictions.
- predict future behavior using multiple variables.
- predict intensity based on barometric pressure readings.
- determine the significance of predictions.

RESOURCES

BOOKS, PAMPLETS, AND PERIODICALS

Kellin, John: *When a Hurricane Strikes: The Book That's A Survival Guide*, Image Group, 1993

Morgan, Sally: *Reading About Hurricanes*, Watts, 2000

Fitzpatrick, Patrick: *Natural Disasters: Hurricanes: A Reference Handbook*, ABC-Clio, 1999

Davies, Pete: *Inside the Hurricane: Face to Face with Nature's Deadliest Storms*, Henry Holt, 2000, 1st edition

Hood, Susan: *Hurricanes*, Simon Spotlight, 1998, 1st edition.

Williams, Jack: *USA Today: The Weather Book*, Vintage Book, New York, 1997

Watt, Fiona and Wilson, Francis: *Weather and Climate*, Usborne Publishing, London, 1992

WEB SITES

GIFTS (Geostationary Imaging Fourier Transform Spectrometer)
http://danspc.larc.nasa.gov/GIFTS
http://nmp.jpl.nasa.gov/eo3/index.html
http://its.ssec.wisc.edu/~bormin/GIFTS/

The Hurricane Hunters
http://www.hurricanehunters.com

The Weather Channel
http://weather.com

Riverdeep
http://riverdeep.net

Hurricane Basics
http://www.noaa.gov
http://www.fema.gov/library/98survstrm.pdf

Hurricane Forecasting
http://hurricanes.noaa.gov/prepare/title_fore.htm
http://www.nhc.noaa.gov

Hurricane Tracking Charts
http://www.nhc.noaa.gov
http://stormcarib.com/guide.htm#unit

Hurricane Information for Kids (games, certificates, information, etc.)
http://www.fema.gov/kids/
http://www.miamisci.org/hurricane/insideahurricane.html

Hurricane Safety
http://www.redcross.org/disaster/safety/hurrican.html
http://weather.com/safeside/tropical/index.html

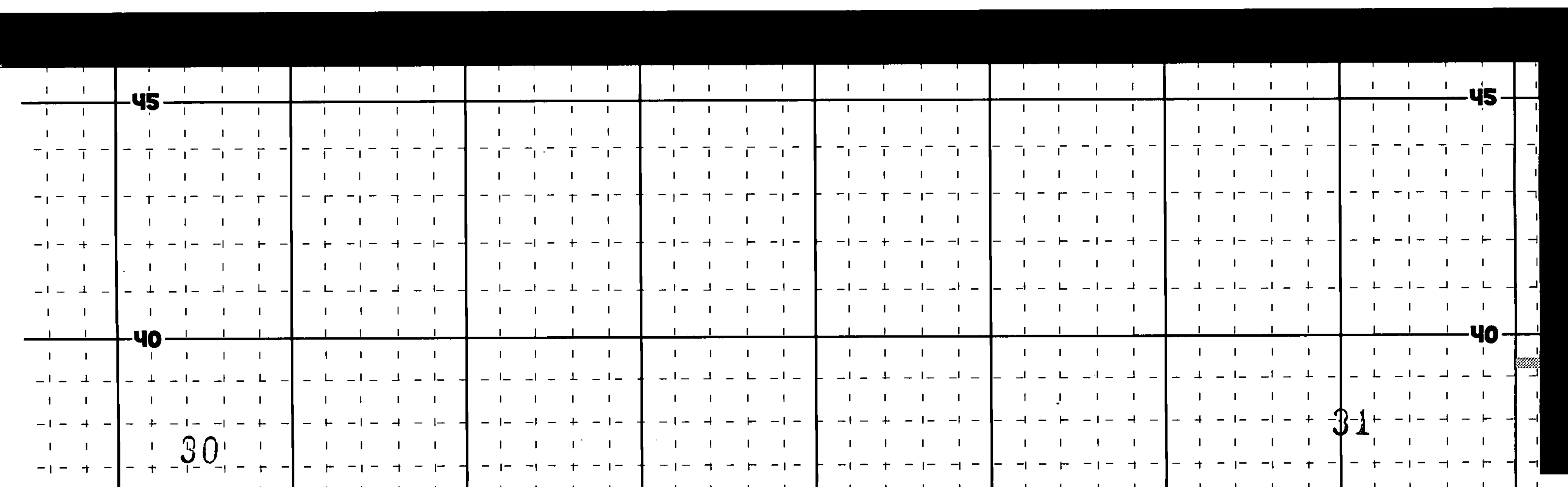
Hurricane Lesson Plans/Activities
http://asd-www.larc.nasa.gov/ceres\ASDceres.html
http://www.strategies.org/Climate/Hurricane.pdf

Score Card

Level 1	______
Level 2	______
Level 3	______
Level 4	______
Total	______

Saffir-Simpson Scale

Maximum Sustained Wind Speed	Classification	Map Reference Color
	Tropical Depression	
35 - 73 mph	Tropical Storm	
74 - 95 mph	Category I Hurricane	
96 - 110 mph	Category II	
111 - 130 mph	Category III	
131 - 155 mph	Category IV	
>155 mph	Category V	



Hurricane Tracking Map

Formula 1

$$s = \frac{d}{t}$$

Where: s = speed
d = distance
t = time

Formula 2

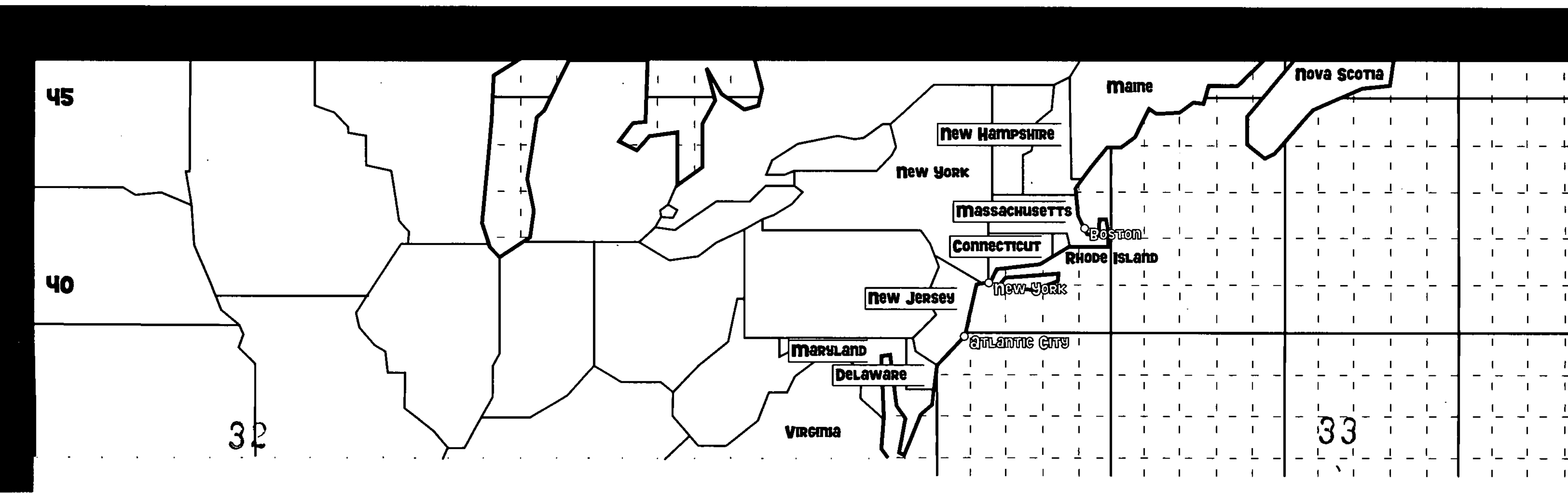
Watch = Speed X 36

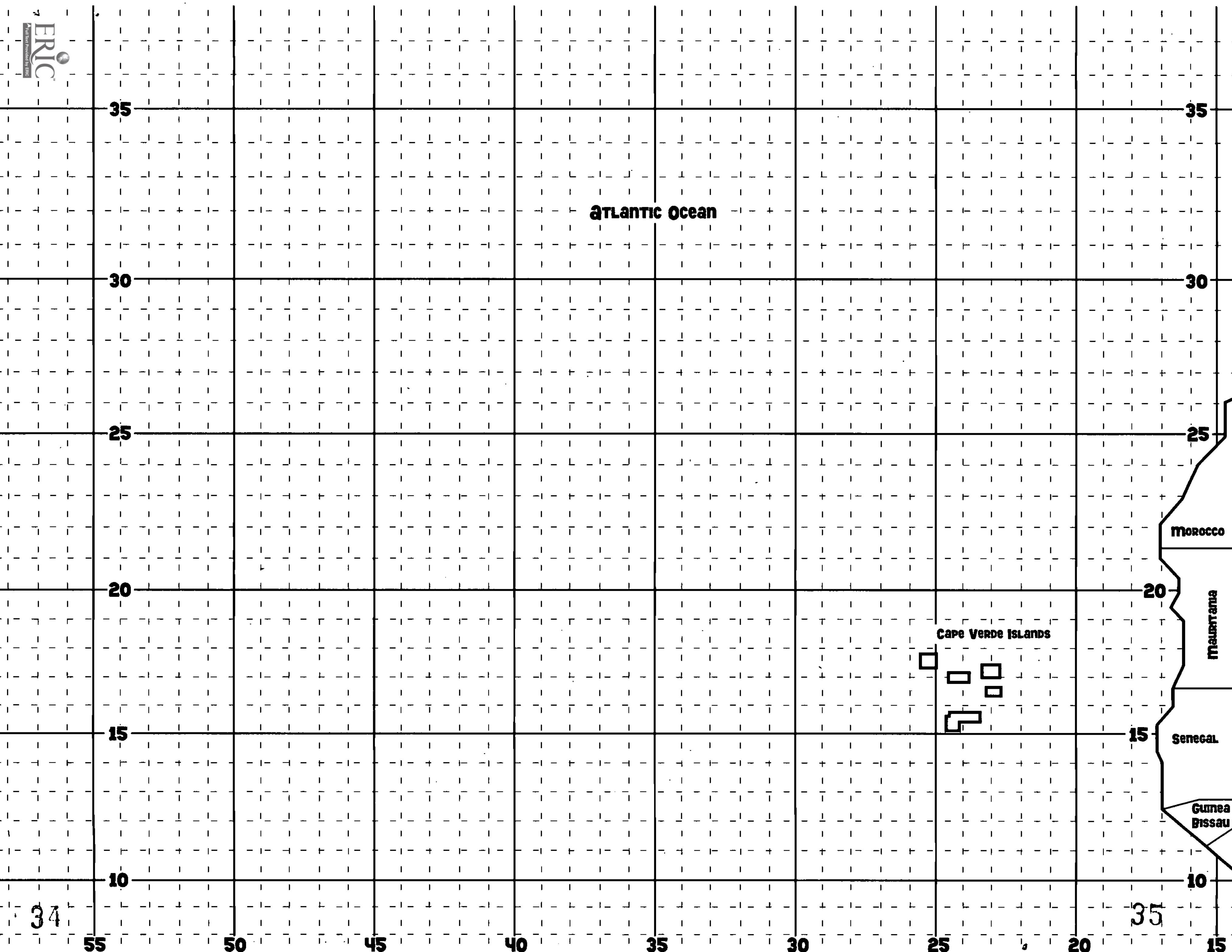
Formula 3

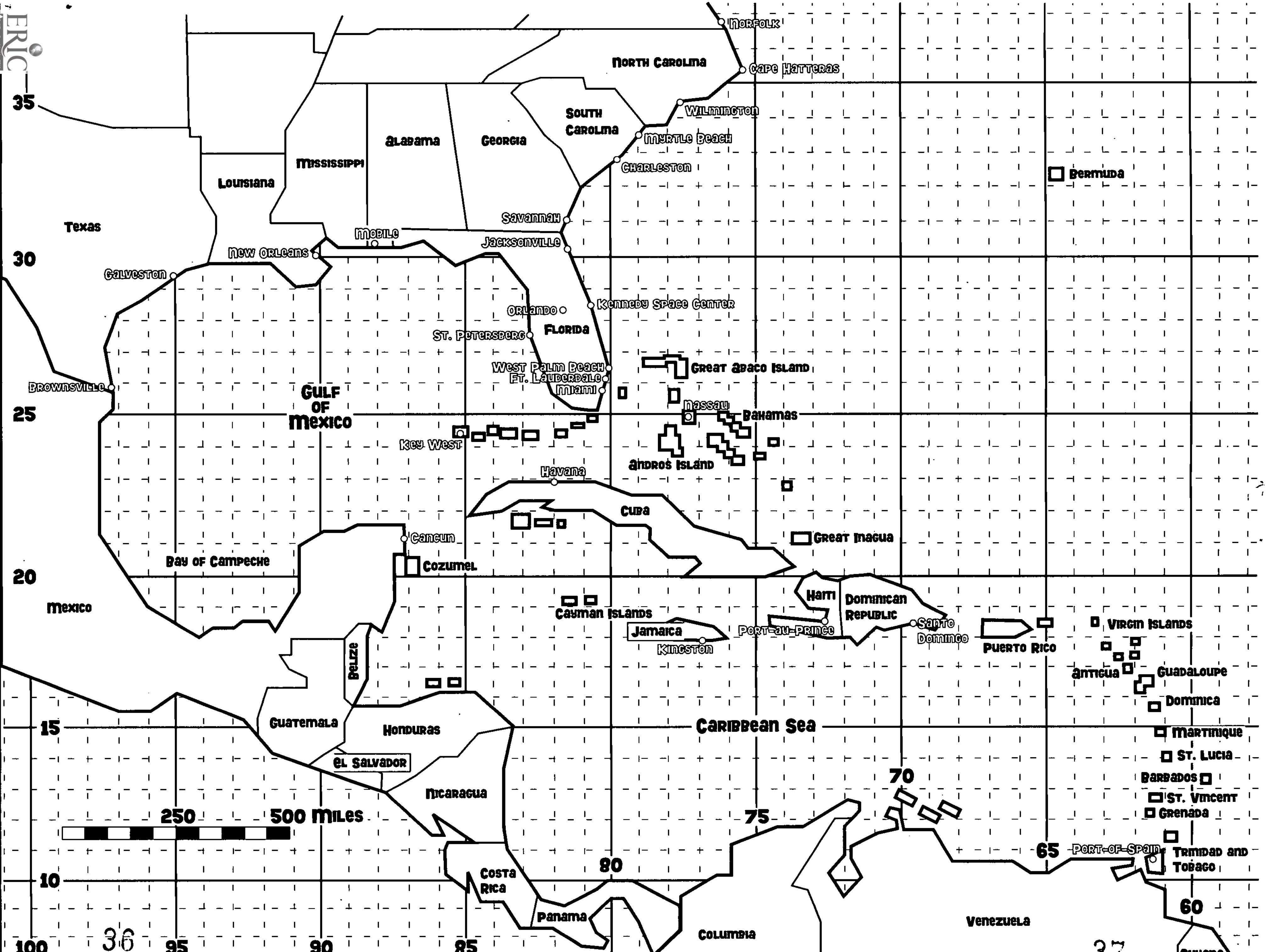
Warning = Speed X 24

Watch/Warning

Watch = Hurricane or Tropical Storm conditions expected within 36 hours
Warning = Hurricane or Tropical Storm conditions expected within 24 hours




Atlantic Ocean
Cape Verde Islands
Morocco
Mauritania
Senegal
Guinea Bissau



Norfolk
Cape Hatteras
North Carolina
Wilmington
South Carolina
Myrtle Beach
Charleston
Alabama
Georgia
Mississippi
Louisiana
Savannah
Jacksonville
Texas
Mobile
New Orleans
Galveston
Kennedy Space Center
Orlando
Florida
St. Petersberg
West Palm Beach
Ft. Lauderdale
Miami
Great Abaco Island
Nassau
Bahamas
Andros Island
Brownsville
Gulf of Mexico
Key West
Havana
Cuba
Great Inagua
Cancun
Cozumel
Bay of Campeche
Mexico
Haiti
Dominican Republic
Santo Domingo
Port-au-Prince
Cayman Islands
Jamaica
Kingston
Puerto Rico
Virgin Islands
Antigua
Guadaloupe
Dominica
Martinique
St. Lucia
Barbados
St. Vincent
Grenada
Trinidad and Tobago
Port-of-Spain
Belize
Guatemala
Honduras
El Salvador
Nicaragua
Caribbean Sea
Costa Rica
Panama
Columbia
Venezuela
250
500 Miles
35
30
25
20
15
10
100
95
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75
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60

36

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STUDENT CUE CARDS

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