HAZARDOUS WEATHER

HURRICANES

TEACHER'S GUIDE

Project ATMOSPHERE

This guide is one of a series produced by Project ATMOSPHERE, an initiative of the American Meteorological Society. Project ATMOSPHERE has created and trained a network of resource agents who provide nationwide leadership in precollege atmospheric environment education. To support these agents in their teacher training, Project ATMOSPHERE develops and produces teacher's guides and other educational materials.

For further information, and additional background on the American Meteorological Society's Education Program, please contact:

American Meteorological Society
Education Program
1200 New York Ave., NW, Ste. 500
Washington, DC 20005-3928
www.ametsoc.org/amsedu

This material is based upon work initially supported by the National Science Foundation under Grant No. TPE-9340055.

Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Foreword

This guide has been prepared to introduce fundamental understandings about the guide topic. This guide is organized as follows:

Introduction

This is a narrative summary of background information to introduce the topic.

Basic Understandings

Basic understandings are statements of principles, concepts, and information. The basic understandings represent material to be mastered by the learner, and can be especially helpful in devising learning activities in writing learning objectives and test items. They are numbered so they can be keyed with activities, objectives and test items.

Activities

These are related investigations. Each activity typically provides learning objectives, directions useful for presenting and completing the activity and questions designed to reinforce the learning objectives.

Information Sources

A brief list of references related to the guide topic is given for further study.

Overview

Weather is variable, from the gentle breezes of a balmy evening to the heavy wind and rain of a late afternoon thunderstorm. Hazardous weather, such as thunderstorms, hurricanes, and winter storms — covered in this and related guides — can cause property damage, bodily injury or even death. With the necessary information, proper preparation, and sensible reactions, most people can protect themselves and to some extent their property from the ravages of most kinds of hazardous weather.

Hazardous weather may affect anyone, anywhere in the world at any time. The table below shows the annual approximate numbers of various types of severe weather for several countries worldwide. The United States actually has the greatest variety and occurrence of threatening weather conditions.

Comparison of Weather Risks[1]

Country	Severe Thunderstorms	Tornadoes	Severe Winter Storms	Hurricanes, Tropical Cyclones, Typhoons	Flash Floods
U S A	10,000/yr	1000/yr	10/yr	10/yr	1000/yr
Australia	500	< 100	0	10	100
Canada	500	10	20	0	10
France	100	< 10	10	0	10
Germany	100	< 10	10	0	10
Japan	500	< 10	10	10	50
United Kingdom	100	10	10	0	10
Russia/former USSR	5,000	10	20	0	100
China	10,000	< 10	5	20	500

[1] Data courtesy of NOAA, NWS.

Hazardous weather in the United States result in hundreds of lives lost each year with total property losses typically reaching into the billions of dollars. These are ample reasons why everyone should keep track of the weather and understand what to do if severe weather occurs.

The U.S. National Weather Service, an office of the National Oceanic and Atmospheric Administration, has the responsibility of warning people in the country of the possible impact of a severe weather-related event. Warning programs have been developed to

inform the public of the weather hazard and to help initiate appropriate adaptive measures. Prompt response to such information can save lives, reduce injuries, and lessen property damage.

Suggested Activities:

1. Plot the numbers appearing in the table on a world map to highlight the types and numbers of weather threats around the globe. Does there appear to be any particular geographical pattern to the frequency of the different kinds of weather risks?

2. Which country listed has the greatest variety of hazardous weather and need for timely weather forecasts, watches and warnings?

3. Of the threats listed, which is of greatest concern in your local area? What should you, your family, and your community do to try to adequately prepare and respond to the threat or threats?

4. What was the most recent hazardous weather you and/or your community faced? What was done or could have been done to lessen its effects?

5. Does your family, school, and community have a plan for all types of hazardous weather that might occur? What has been done or should be done? Who should do it?

6. What are the basic safety rules individuals should follow in facing the different kinds of hazardous weather? (Find information from your local National Weather Service office or local chapter of the American Red Cross for safety rules and hazardous weather preparedness and response.)

Hazardous Weather Watches and Warnings

The National Weather Service has terminology to alert the public to weather conditions that may require action to save lives and protect property. These terms accompany the specific type of severe weather to be encountered such as thunderstorms, tornadoes, high winds, floods and flash floods, and hurricanes.

A ***watch*** is issued when there is a threat of that weather developing in a specified area over a certain period of time.

A ***warning*** is issued when that weather threat has been observed (visually or by radar) in a given location. One should take immediate steps to avoid imminent danger.

Basic Understandings: Hurricanes

Hurricane Development

1. A hurricane is an intense rotating storm system that forms over warm tropical waters in the late summer or early fall.

2. Hurricanes are circular in shape, about 300 miles across, and have winds over 74 miles per hour within 30 miles of the center.

3. The formation of a hurricane requires a low pressure disturbance over a large expanse of warm water. The evaporation of the water will intensify the resulting storm.

4. This formation must be far enough from the equator so that winds will *circulate* around a center of low pressure due to the *Coriolis force*. The Coriolis force is too weak near the Equator to create the needed rotation.

5. Certain wind patterns at various altitudes are also needed to ensure that the developing hurricane will not simply blow apart.

6. The hurricanes that strike North America form in the tropical North Atlantic and Caribbean and move on a westerly to northerly track, steered by the prevailing winds. They strike the mainland on either the Gulf or Atlantic coasts.

7. The *tropical disturbance* stage of hurricane development is characterized by a collection of thunderstorms forming in the easterly flow over warm tropical waters with only a slight rotation.

8. The *tropical depression* stage is a well-defined center of low pressure with winds of 22 to 37 miles per hour.

9. The *tropical storm* stage is characterized by an intense center of low pressure and winds of between 38 and 74 miles per hour.

10. The *hurricane* stage occurs when the wind speed exceeds 74 miles per hour.

Hurricane Features

11. The major feature within a hurricane is the *eye*, a small region of relatively calm and clear air in the center, ten miles or so across.

12. The eye is surrounded by the *eye wall* where the weather is most severe with high winds and heavy precipitation.

13. Feeding into the wall cloud region are *spiral rain bands*, often embedded with vigorous thunderstorms.

14. The forward movement of hurricanes is slow, usually up to about 15 miles per hour in the lower latitudes.

15. The path of the hurricane is determined by the complex interactions with wind currents aloft and the existing large-scale weather patterns. The resulting path can be erratic and difficult to forecast.

16. In a hurricane, the observed wind speed is largely determined by the combined forward and spinning motions of the storm. On one side of the eye, the wind speed is *increased* by the forward motion of the storm and on the other side, the wind speed is *decreased* by this motion.

17. Since hurricanes get their energy from the evaporation of warm tropical water, as they move over colder water or land, they lose their energy source and weaken in intensity.

Hurricane Hazards

18. The low pressures and high wind speeds associated with hurricanes create huge mounds of water called *storm surges* which historically have caused 90% of all hurricane deaths. Large-scale evacuations of people from low-lying areas can prevent the massive loss of like due to such flooding.

19. Hurricane winds have been recorded at speeds up to 200 miles per hour. Beyond the direct damage caused by such winds, wind-driven waves on top of the storm surge compound the flooding problem by battering and eroding the coastal landscape and structures.

20. The National Weather Service issues a ***hurricane watch*** when there is the threat of a hurricane within 24 to 36 hours.

21. A ***hurricane warning*** is issued when the threat of a hurricane is within 24 hours or less.

Introduction: Hurricanes

What is a hurricane?

A hurricane is an intense rotating storm system that forms over tropical waters. The typical hurricane is roughly circular in shape and about 300 miles across. Winds of hurricane speed — 74 miles per hour and higher — are confined to a relatively small area typically within 30 miles of the center of the storm's path.

What causes hurricanes?

Hurricane formation requires the following:

- an initial low pressure disturbance over a large expanse of warm water; evaporation of this water will produce thunderstorm clouds which can intensify the resulting storm.

- a location far enough from the Equator so that winds will *circulate* around a center of low pressure. The Coriolis force (a consequence of Earth's rotation) is the source of this circulation. There is no Coriolis force at the Equator; the Coriolis force increases as latitude increases.

- certain wind patterns at various altitudes, to insure that the developing storm will not simply blow apart.

Hurricanes usually form in late summer or early fall. Many hurricanes that strike North America form in the tropical waters of the Atlantic Ocean or Caribbean Sea, move on a westerly to northerly track, steered by the prevailing wind direction, and strike the mainland on either the Gulf or Atlantic coasts.

Stages of Hurricane Development

Tropical Disturbance – The first stage is a collection of thunderstorms forming in the easterly flow over warm waters with only slight rotation.

Tropical Depression – Next the storm develops a well-defined center of low pressure with winds of 22 to 37 miles per hour.

Tropical Storm – Next the storm becomes an intense center of low pressure and carries winds of between 38 and 74 miles per hour.

Hurricane – When the wind speeds are 74 miles per hour and higher, the storm is considered a hurricane.

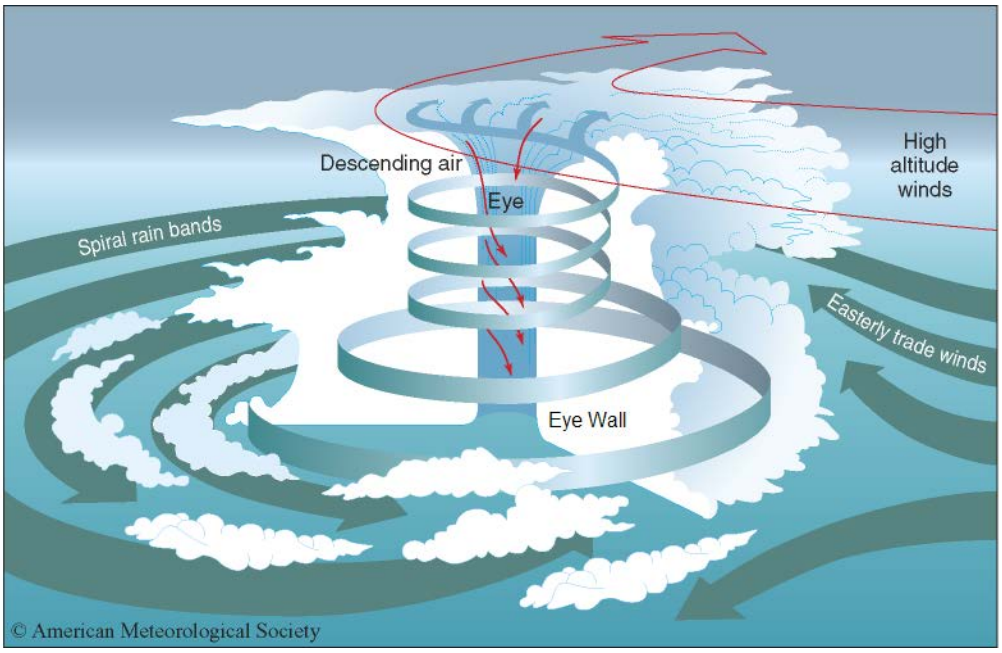
Hurricane Structure

Here are the major features within a hurricane (see diagram below):

Eye – The eye is the small region of relatively calm and clear air in the center; the eye may be only ten miles or so across.

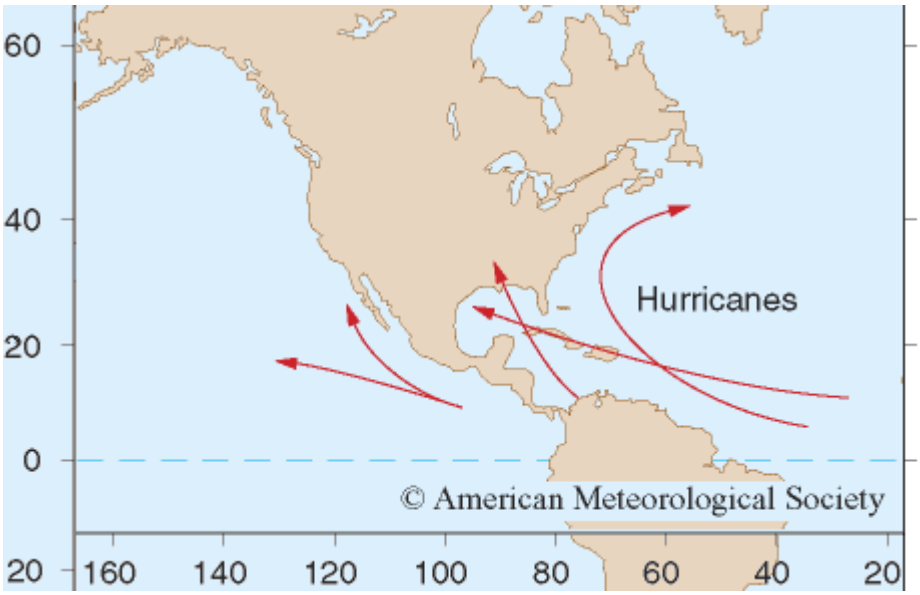
Eye Wall – The eye is surrounded by clouds that make up the eye wall; here the weather is most severe with high winds and heavy precipitation.

Spiral Bands – Feeding into the wall cloud region are spiral bands of clouds, often composed of strong thunderstorms.



Motion of Hurricanes

The forward movement of hurricanes is relatively slow, usually up to about 15 miles per hour in the lower latitudes. The path of the hurricane is determined by the complex interactions with wind currents aloft and the existing large-scale weather patterns. The resulting paths can be erratic and difficult to forecast. The diagram below shows the paths of several hurricanes.



The hurricane is a system of winds rapidly spiraling into the low pressure center (counterclockwise in the Northern Hemisphere) as it moves slowly forward. On the right side of the storm's track, the storm's forward motion reinforces the wind. On the other side of the track, the air and storm motions compete, reducing wind speeds. Consequently, storm damage is usually most severe north and east of the eye's landfall and can vary considerably over distances as small as thirty miles.

Energy Source

Hurricanes get their energy from evaporation over large expanses of warm tropical water. Evaporation from warm water surfaces produces water vapor that carries tremendous amounts of energy into the growing storm. Subsequent condensation of this water releases this energy and intensifies the storm.

As hurricanes move over colder water or land, they lose their warm-water energy source and weaken in intensity.

Hurricane Damage

Major damage due to a hurricane is caused by two factors:

Storm Surge –Many people are surprised to learn that historically 90% of hurricane deaths are due to high water rather than high winds. Due to the low pressure and strong winds, hurricanes create a huge mound of water called a storm surge, especially in shallow coastal waters. As the surge sweeps ashore, the high water can flow right over sea walls and destroy protective sand dunes; when the surge coincides with high tide, the increase in water level can be as much as twenty feet. Large-scale

evacuations of people from low-lying areas, such as the Gulf Coast or the Outer Banks of North Carolina, prevent massive loss of life due to such flooding.

Wind Damage – Hurricane winds have been recorded at speeds up to 200 miles per hour. Beyond the damage caused directly by such winds, wind-driven waves on top of the storm surge compound the flooding problem by battering and eroding coastal features.

Watches and Warnings

These are issued by the National Weather Service and indicate that there is a threat of a hurricane within a particular time period.

hurricane watch:	threat of a hurricane *within 24 to 36 hours*
hurricane warning:	threat of a hurricane *within 24 hours or less*

Activity: Track of Hurricane Jeanne

After completing this exercise, you should be able to:

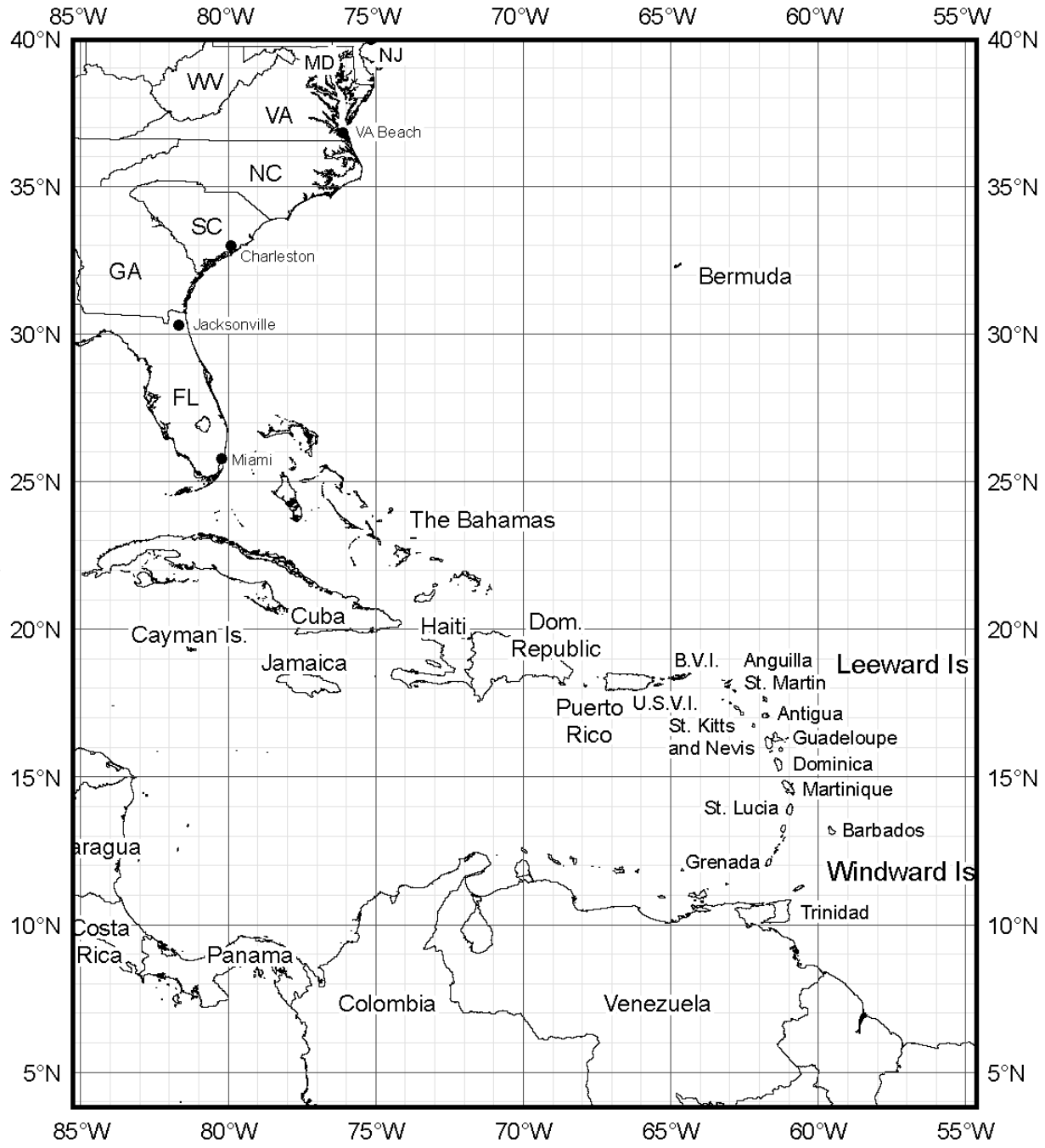
- describe how a hurricane can be tracked.
- observe the unpredictable path of a hurricane.
- use the track of a hurricane to plan a disaster relief program.

The map provided shows and area of the Atlantic Ocean and Caribbean Sea off the East Coast of North America. Use the map to track the path of Hurricane Jeanne from the positions given in the accompanying table. Each position shows the center of the storm for the time indicated in the table. These positions are given as latitude and longitude. Longitude advances toward the left (west) and latitude advances upward (north). Begin by plotting the positions number 1 to 5 from the table. Connect these points with line segments. Answer the questions below at that point.

Hurricane Jeanne, 13 – 28 September 2004

Date	Time (UTC)	Position #	N. Latitude	W. Longitude	Wind Speed (kt)	Stage
9/13	1800	1	15.9	60.0	25	TD
9/14	1200	2	16.7	63.5	50	TS
9/15	1800	3	18.1	66.2	60	TS
9/17	0600	4	19.4	69.9	55	TS
9/18	0600	5	20.4	72.5	45	TS
9/18	1200	6	21.2	72.8	45	TS
9/19	1800	7	24.2	72.3	45	TS
9/20	1800	8	27.2	71.4	75	H
9/22	0000	9	27.2	68.9	80	H
9/23	0000	10	25.7	69.0	85	H
9/24	0000	11	26.0	70.4	70	H
9/24	1200	12	26.2	72.2	80	H
9/26	0000	13	27.1	79.4	105	H
9/26	0600	14	27.3	80.6	95	H

UTC is Universal Time Coordinated, 4 hours ahead of local Atlantic Standard Time.



(Adapted from the Atlantic Basin Hurricane Tracking Chart, NHC, http://www.nhc.noaa.gov/tracking_charts.shtml)

1. If you were a meteorologist, what would you tell people living in the immediate area? What about the people in Florida? What is the anticipated landfall point for the U.S. mainland? When might that occur?

2. If you were in charge of emergency management for the area to the west of the storm's position, what action would you take, if any? Consider that it will take

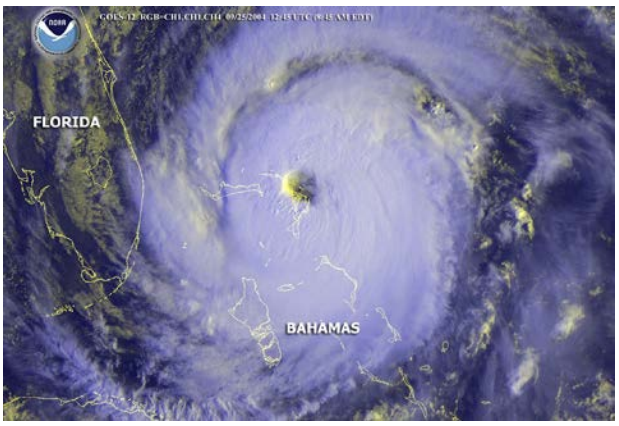
several hours to alert people in your exposed areas and allow them to evacuate, if needed. (The more people who at risk, the more time it will take to move them, and the time of day should be considered.)

3. What types of emergency personnel and supplies will be needed if widespread damage occurs?

Next, continue to plot point 6 and connect to the path. Consider the questions again, are any changes needed?

Plot 7, 8 and consider the questions. Then plot 9 and consider the questions. Follow with point 10, then point 11, finally point 12 considering if the answers you have given to the questions need to be reconsidered. Lastly, plot points 13 and 14. How did your track and time projections work out?

Jeanne formed from a tropical wave off Africa on 7 September. The wave slowly strengthened to a tropical depression and then storm by 14 September. As Jeanne moved over Haiti, the heavy rains caused mudslides that claimed the lives of 3,000 people and washed away 200,000 homes. In the U.S. 4 deaths were directly caused by Jeanne along with property losses of 6.9 billion dollars. That year, Jeanne was one of three hurricanes to cross central Florida within one month.



Hurricane Jeanne (NOAA)

2004 central Florida hurricane tracks (USGS)

Additional Activities:

a. When a tropical storm or hurricane is reported, monitor radio and television for information on the storm's progress. Plot the position of the storm's center on a classroom map or tracking chart. Also mark the coastline along which hurricane watches and warnings have been issued. For more information, see *http://www.nhc.noaa.gov*.

b. Invite persons who have lived through hurricanes to speak about their experiences to the class.

c. What can individuals, families, and communities in coastal areas do to meet the hurricane threat? If you live in a coastal area, what are the preparedness and response plans of your family and community?

d. For more information on hurricane and general severe weather preparedness, see *http://www.nws.noaa.gov/com/weatherreadynation/*.

Information Sources

Books

Moran, Joseph M. Weather Studies: Introduction to Atmospheric Science, 5th Ed. Boston, MA: American Meteorological Society, 2012.

Periodicals

Weatherwise. Bimonthly magazine written in association with the American Meteorological Society for the layperson. Weatherwise, 1319 Eighteenth St., NW, Washington, DC 20036.

USA Today. National newspaper with extensive weather page. Available at local newsstands and by subscription.

Radio and Television

NOAA Weather Radio. The voice of the National Weather Service and All Hazards Emergency Alert System. Local continuous broadcasts from over 1000 transmitting stations nationwide.

The Weather Channel. A continuous cable television program devoted to reporting weather. Includes frequent broadcast of local official National Weather Service forecasts.

Internet

DataStreme Atmosphere (*www.ametsoc.org/amsedu/dstreme/*). Atmospheric education distance-learning website of the AMS Education Program.

JetStream – Online School for Weather (*www.srh.noaa.gov/jetstream/*). Background weather information site from the National Weather Service.