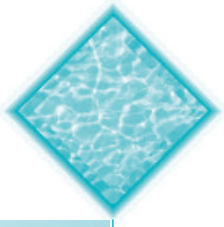
Chapter 2

Water: It's Magic

*"If there is magic on this planet,
it is in water."*

— Loren Eisley, Naturalist and Philosopher



*"One question I ask of you:
Where flows the water?
Deep in the ground in the gushing spring,
A water of magic power — The water of life!
Life! O give us this life!"*

— Native Hawaiian poem

KEY IDEAS

- Water is critical for all life on Earth.
- Water has many amazing chemical and physical properties.
- Most of the water on Earth is salt water.
- Only 3 percent of the Earth's water is fresh water and less than 1 percent of the fresh water is available for use. Most fresh water is frozen in glaciers and polar ice caps.
- Water is continuously circulating between the sky, land and sea.
- No significant amount of water enters or leaves the global water cycle.
- Water does enter and leave Florida's water cycle.
- Rainfall in Florida varies with season and location.
- Florida is susceptible to extreme weather events including tornadoes, hurricanes, floods, thunderstorms and droughts.
- Florida's climate is influenced by global patterns.

VOCABULARY

Atom
Capillarity
Condensation
Drought
El Niño
Evaporation
Evapotranspiration
Flood
Gas
Global warming
Ground water
Humid subtropical
Hurricane
Hydrologic divide
La Niña
Liquid
Molecule
Precipitation
Saltwater intrusion
Solid
Solvent
Stormwater runoff
Surface tension
Surface water
Tornado
Transpiration
Tropical savanna
Water budget
Water cycle

The wonders and life-giving powers of water have awed and intrigued people throughout the world. To many, water came first in the unfolding of creation. Only after water did land appear, then plants and animals, and then humans. The Winnebago Indians of Wisconsin speak of the Earthmaker. Sitting alone in empty space, the Earthmaker began to cry, and as his tears fell, the waters of the Earth formed. For the Maori of New Zealand and the Crow Indians of the North American plains, in the beginning there was no land on Earth, only water. The Book of Genesis describes Earth before creation as dark, with water covering all the land. Scientists believe life on Earth began in water, where it remained for 3 billion years. About 450 million years ago, plants began to grow out of water, but only on wet ground (Hooper and Coady 1998). Today, water covers 75 percent of the Earth.

Water is essential for all life processes. Plants and animals are between 50 and 97 percent water. The human body is 70 percent water. Protoplasm, the basic material of all living cells, is a solution of fats, carbohydrates, proteins, salts and other chemicals in water. Sap in plants and blood in animals are largely water. Humans can live almost 30 days without food, but only about three to four days without water.

Water's cleansing, healing and renewing powers are unmatched by any other resource on Earth. Religions baptize their initiates in water, and the aged and infirm continue to flock to springs thought to have special healing powers. Water is

IN THE BEGINNING

The world was covered with water, and Old Man and all the animals floated about on a raft. Old Man sent a beaver to bring up some mud, but the water was too deep. Old Man next sent a loon but the water was still too deep. At last he dispatched a muskrat. After a long time, the muskrat surfaced with a clump of mud in its paws. Old Man made the land and all the people from the mud retrieved by the muskrat.

— Plains Indians

The Sun-father and the Moon-mother ordered their children to leave the heavens and to live on the Earth. But Earth was completely flooded with water, and the children were afraid. The elk, the bravest of all animals, went with them. The elk dove into the water and called for the wind to dry the land. Joyous, the elk rolled on the new land, and plants sprang up from the loose hair he left behind.

— Osage Indians

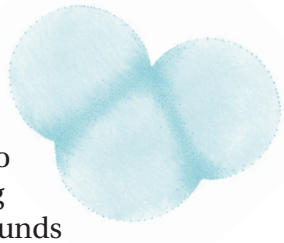
Source: Feder 1997

fun as well as awe-inspiring and is the single most sought-after recreational resource on Earth.

Water and the lack of water can also bring death and destruction. People have always feared the devastating effects of floods, droughts and storms. Modern technology has helped us predict these events and prepare for them, but their occurrence is still largely beyond our control.

Water's Structure

Water has some remarkable chemical and physical properties. The water **molecule** is simple: two hydrogen **atoms** bound to one oxygen atom. An extremely strong bond called a covalent bond connects these atoms. The two hydrogen atoms are always at an angle of exactly 104.5 degrees from each other, making all diagrams of water molecules "look like the ears on a round head of a panda" (Watson 1988). Because the fit between the atoms is so perfect, water is among the most stable compounds in nature. The tiniest droplet of water contains more than 300 trillion water molecules.



WATER'S AMAZING PROPERTIES

- Water is the only substance that exists in nature as a **liquid**, a **solid** and a **gas**.
- Water circulates continuously between land, sky and sea.
- Pure water is odorless, transparent and, for many people, tasteless. Taste is often from minerals or other items dissolved in the water.
- Unlike most liquids, water expands rather than shrinks when cooled.

  Thus, water is lighter in its solid state than it is in its liquid state. This is why ice floats. Imagine how different the world would be if ice sank. In colder climates, rivers, lakes and ponds would be frozen solid, and fish and other aquatic life would be unable to survive the winter.
- Water holds heat much better than air does. Air temperature may change rapidly, but water temperature changes slowly. On a cool summer night, seawater is still warm enough for a swim.

- Water is the universal **solvent**. This means that more substances will dissolve in water than in other liquids. This property makes water very useful for washing clothes, dishes and human skin. It also means water becomes contaminated or polluted very easily.

- Water shapes the surface of the Earth. In combination with gravity, wind and expansion and contraction caused by freezing and thawing, water can dissolve rocks, wear down mountains and hills, and sculpt drainage basins.

- Water has **surface tension**. Surface tension occurs when two substances that do not mix freely, such as air and water, come into contact. The water molecules draw closer together and cling or adhere to each other like little magnets, causing the surface to shrink (Wick 1997). Because of surface tension, insects can skate across the surface of a pond, which seems to have a skin. Surface tension also holds molecules together in drops.

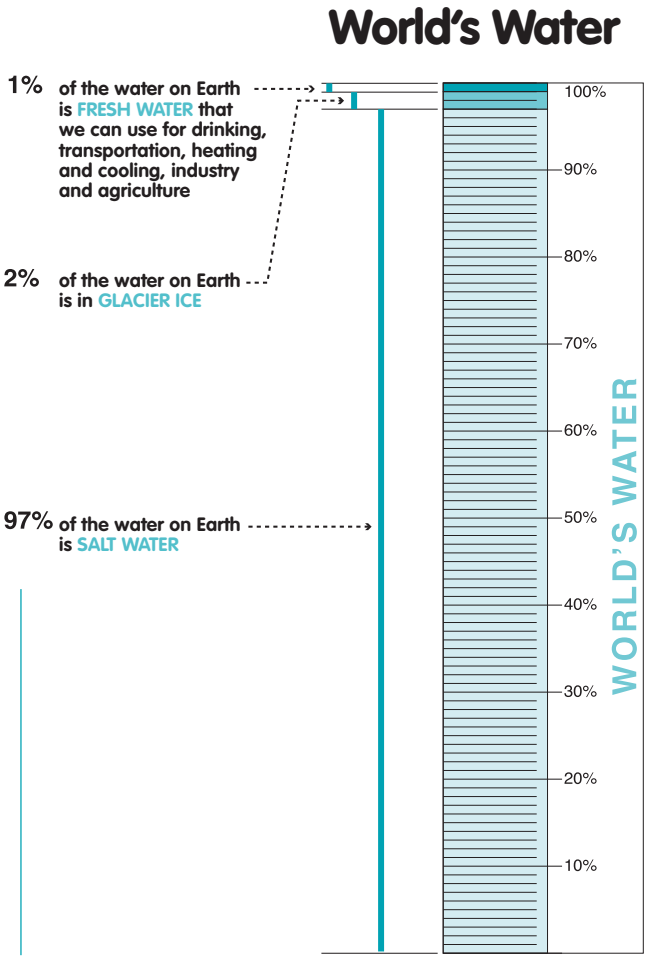
- Water has **capillarity**. Capillaries are long, slender, tubelike structures. Water rises in capillaries because of the attraction of water molecules to each other and to the molecules on the side of the solid capillary. For example, if you rest a straw in a glass of liquid, the liquid rises in the straw above the level of liquid in the glass. This is because of capillarity, which results from the attraction of the water molecules to each other and to the molecules in the straw. Because of capillarity, plants are able to draw water from the ground up through their roots and stems.

Global Water Cycle

Until the late 1980s, scientists assumed the amount of water on Earth was fixed and finite. Now some scientists believe that Earth's water supply may be constantly growing as a result of huge "snowballs" that enter the Earth's gravitational field from outer parts of the solar system. These snowballs, about the size of small houses, are thought to melt and evaporate when they approach the Earth (Frank 1990, cited in Pielou 1998). In any event, this possible addition is relatively insignificant in relation to the vast amount of water constantly on Earth.

Water on Earth today has been here for millions and perhaps billions of years. Scientists believe water originated early in the Earth's history from hydrogen and oxygen in the gas cloud from which our universe formed.

In 1998 in Monahans, Texas, five boys were playing basketball when they heard what sounded like a sonic boom. In a nearby vacant lot, they saw a black rock the size of a grapefruit. One of the boys picked up the still-warm rock and



handed it to his father, who correctly identified it as a meteorite. Inside was a minute amount of liquid water, the first ever found in a meteorite. Scientists believe this water dates from very early in the solar system and may be 4.5 billion years old. This finding supports the theory that water is indeed very ancient. It also suggests that perhaps there were other places in the solar system where life may have developed.

Nearly all of the water on Earth is salt water. Less than 3 percent is fresh water and most of this is locked up in glaciers and polar ice caps. Less than 1 percent of the world's water is fresh water available for human and nature's use.

The water on Earth is continuously circulating between the air or atmosphere, the land and the sea. The ways in which water moves around, above, on and within the Earth is the hydrologic or **water cycle**.

The sun is the energy source for the water cycle, causing water to evaporate from lakes, rivers and oceans, as well as from land surfaces and vegetation. When water evaporates, it changes to a gas (water vapor) and rises in the air. When the water vapor rises and meets cold air, it condenses, forming water droplets, or what we see as clouds or fog. This process is called **condensation**. Water droplets combine into water drops and return to the Earth as **precipitation** in the form of rain, sleet, hail or snow.

Exactly how clouds produce rain has eluded meteorologists until recently. In 1999, Dutch scientists using a supercomputer to model cloud behavior announced that rain is produced when whirling masses of water, a few centimeters in diameter, force water droplets outward by centrifugal force. These droplets then collide and grow. To fall to the ground as precipitation, they need to reach a diameter greater than 20 micrometers (Environmental News Network online, November 16, 1999).

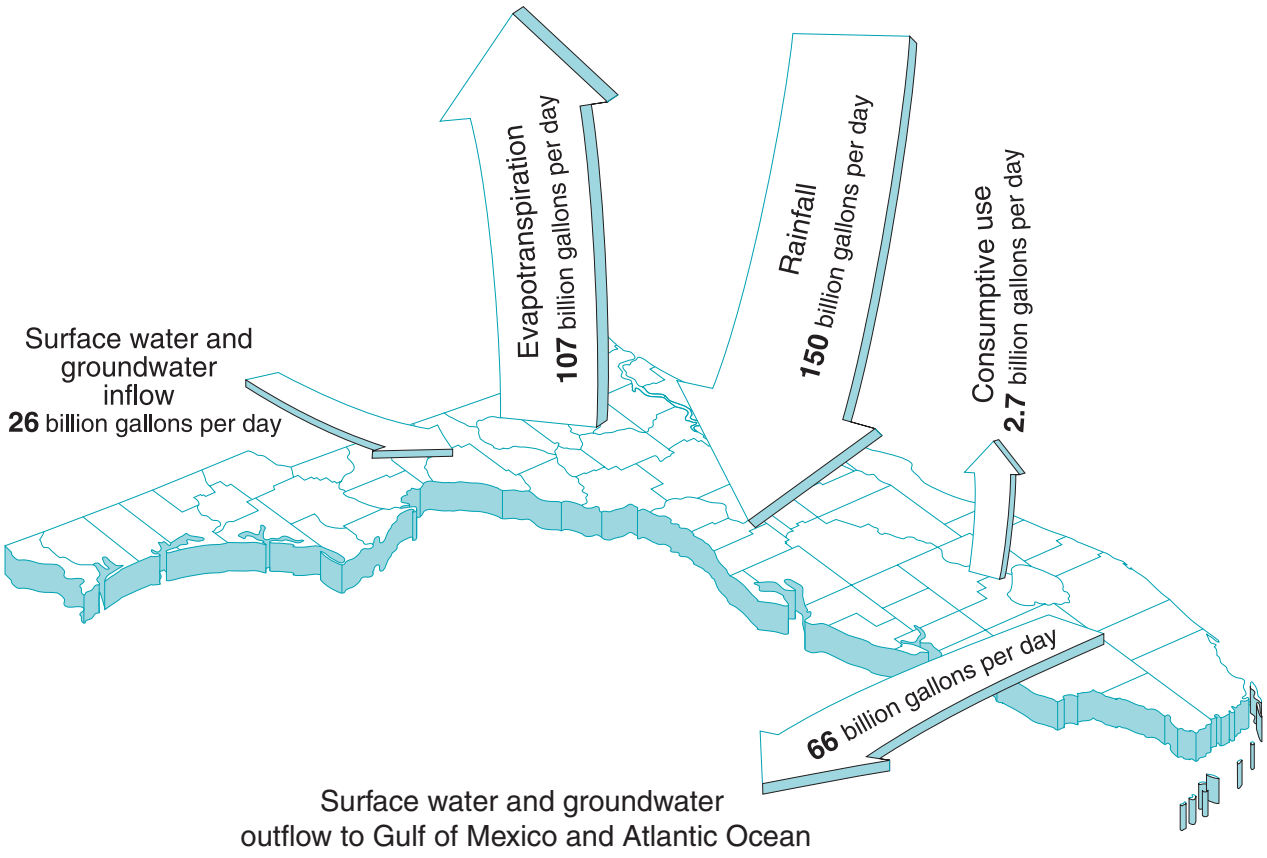
Some rain is absorbed by vegetation or evaporates before it reaches the ground. Some evaporates after it reaches the surface. Some soaks into the ground and is taken up by the roots of plants and then released back into the air through the leaves of the plants in a process called **transpiration**. The combination of **evaporation** and transpiration is referred to as **evapotranspiration**. Some rain soaks beneath the water table into underground units of water-bearing rock called aquifers. The remainder becomes surface or **stormwater runoff** that flows over the ground to wetlands, lakes, ponds, rivers and oceans.

A water molecule's trip from the atmosphere and back may be very long or very short. It may stay in the atmosphere for only a few days or it may remain deeply buried in cavities in the earth or frozen in polar ice caps for thousands of years.

Water Cycle in Florida

No significant amount of water enters or leaves the global water cycle. The water cycle in Florida, however, is an open system. Florida's water cycle includes the flow of **surface water** and **ground water** from Georgia and Alabama into northern and northwestern Florida, as well as outflows to the Atlantic Ocean and the Gulf of Mexico. Hydrologist Garald Parker was the first to discover that neither surface water nor ground water crosses a line snaking across the peninsula from Cedar Key on the Gulf to New Smyrna Beach on the Atlantic (Betz 1984). This line is known as the **hydrologic divide**. South of the hydrologic divide, Florida is an island as far as fresh water is concerned: it totally depends on rainfall for its fresh water, including ground water stored in aquifers. North of the hydrologic divide, Florida receives water from outside the state.

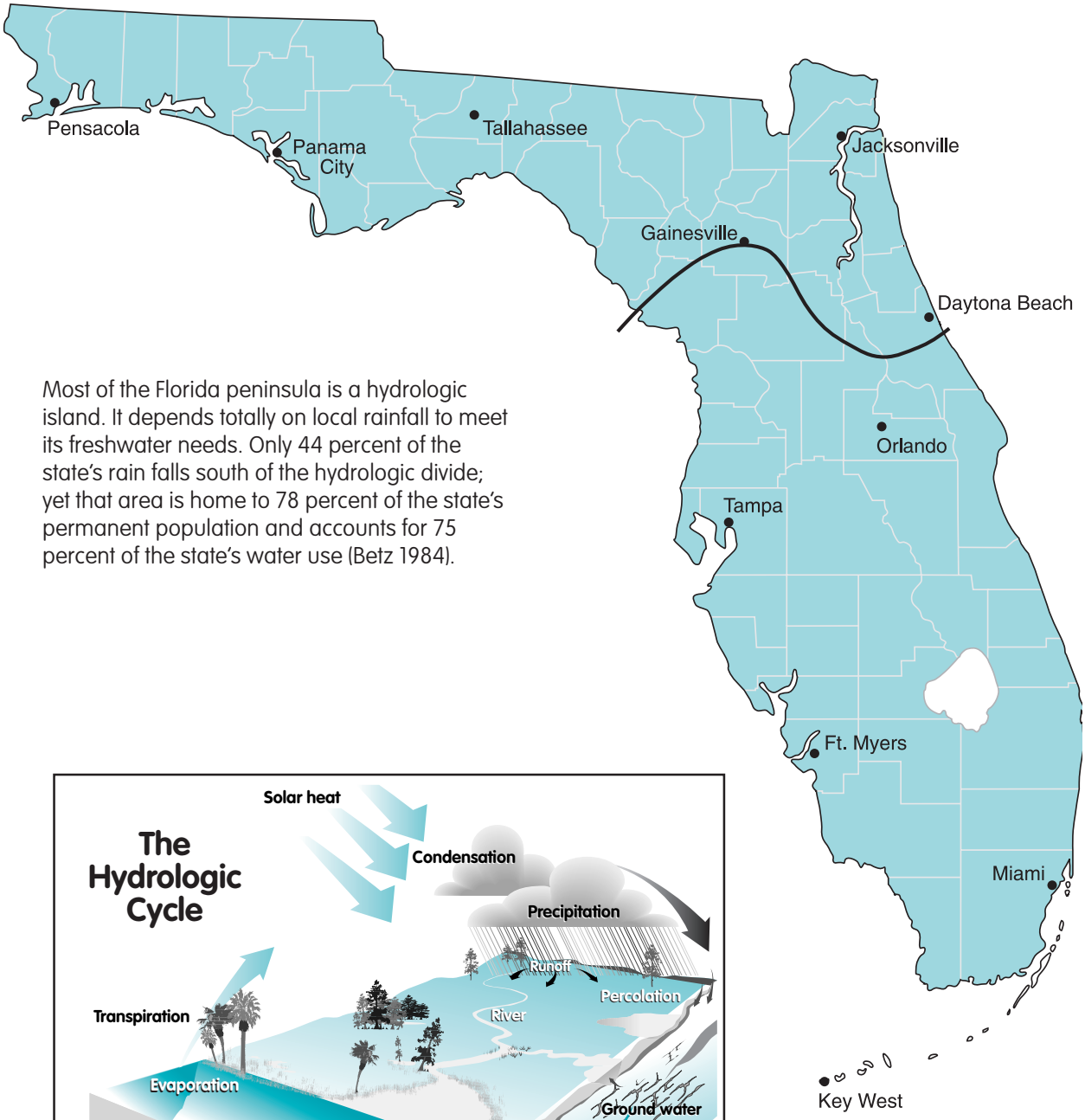
Florida's Water Cycle



Source: Fernald and Purdum 1998

An average of 150 billion gallons of rain falls each day in Florida. Another 26 billion gallons flows into the state, mostly from rivers originating in Georgia and Alabama. Nearly 70 percent of the rain (107 billion gallons) returns to the atmosphere through evaporation and plant transpiration (evapotranspiration). The remainder flows to rivers or streams or seeps into the ground and recharges aquifers. Each day in Florida, 2.7 billion gallons are incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate environment (consumptive use).

Hydrologic Divide



Most of the Florida peninsula is a hydrologic island. It depends totally on local rainfall to meet its freshwater needs. Only 44 percent of the state's rain falls south of the hydrologic divide; yet that area is home to 78 percent of the state's permanent population and accounts for 75 percent of the state's water use (Betz 1984).

Weather and Climate

Florida has two types of climate: **humid subtropical** in the northern two-thirds of the state and **tropical savanna** in the southern third and the Keys. A humid subtropical climate is cooler than a tropical savanna climate, especially in the winter months, and lacks distinct wet and dry seasons. A tropical savanna climate is warm year-round and has distinct rainy and dry seasons. The rainy season in south Florida is in the summer and early fall, when thunderstorms occur nearly every afternoon. The dry season is in the winter. In the United States, only portions of Hawaii share this climate type. A tropical savanna climate is also found in nearly half of Africa, parts of the Caribbean Islands, central and southern Brazil and southeast Asia (Henry, Portier and Coyne 1994).

An average of 135 centimeters (53 inches) of rain falls each year in Florida. Some areas, however, receive considerably more, while some areas receive considerably less than this amount. Wewahitchka in the Panhandle receives an average of 175 centimeters (69 inches) and Key West receives only 102 centimeters (40 inches). Rainfall throughout the state varies considerably from season to season and from year to year, as well as from place to place.

The variability of rainfall in Florida cannot be overemphasized: it is quite possible for it to rain on one side of the street and not the other! Stations within the same city often record large differences in the amount of rainfall. For instance, in the greater Miami area, Miami Beach receives an average of 114 centimeters (45 inches) annually, and the Miami airport receives an average of 143 centimeters (56 inches) annually. Many counties have distinct rainfall zones based on Florida's subtle geographic features, vegetation and water bodies.

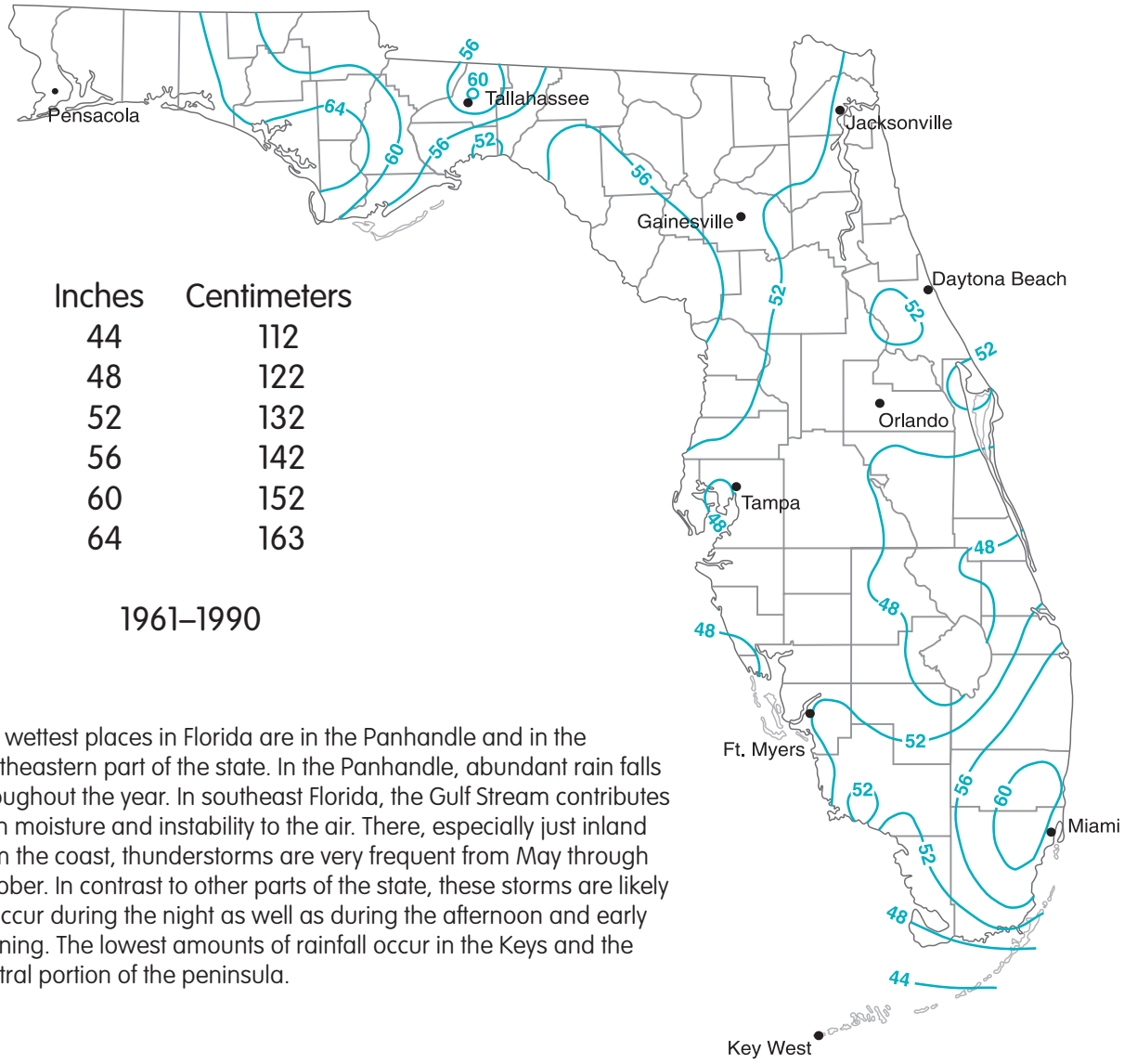
Climate Types

Source: Diane Sterling

Source: Florida Department of Commerce

Source: Henry 1998

Average Annual Rainfall



Inches	Centimeters
44	112
48	122
52	132
56	142
60	152
64	163

1961–1990

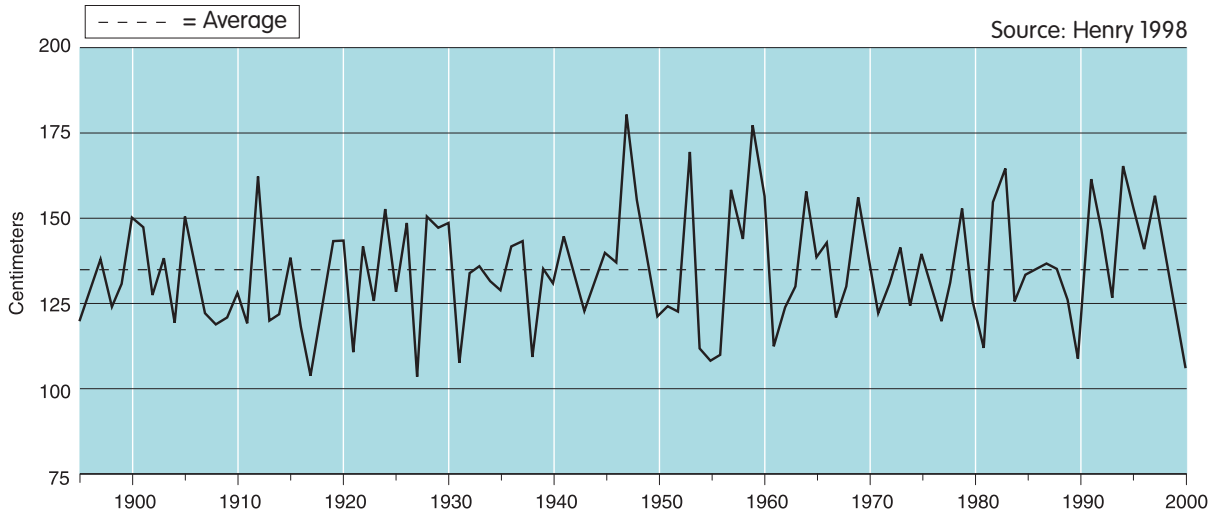
The wettest places in Florida are in the Panhandle and in the southeastern part of the state. In the Panhandle, abundant rain falls throughout the year. In southeast Florida, the Gulf Stream contributes both moisture and instability to the air. There, especially just inland from the coast, thunderstorms are very frequent from May through October. In contrast to other parts of the state, these storms are likely to occur during the night as well as during the afternoon and early evening. The lowest amounts of rainfall occur in the Keys and the central portion of the peninsula.

Source: Henry 1998

FLOODS AND DROUGHTS

Floods and droughts have always been a natural part of Florida's weather pattern. Many natural systems are adapted to and dependent on these events. Floodwaters bring needed nutrients to river floodplains, bays and estuaries. Fires from lightning (more common during droughts) help maintain certain natural communities, such as pine flatwoods, prairies and scrub. Without regular, naturally occurring fires, these communities will succeed to hardwood forests or will burn catastrophically, as occurred in portions of northern and central Florida in the summer of 1998 because of accumulation of pine needles and other fuel. The problems associated with floods and droughts cause more severe impacts because population growth in Florida has been permitted in places that naturally flood or because too much growth has been permitted in places without enough water. Because parts of Florida have large numbers of people, large water demands for agriculture and industry and relatively small capacity to store water, extended periods of low rainfall usually result in water shortages.

Statewide Annual Rainfall



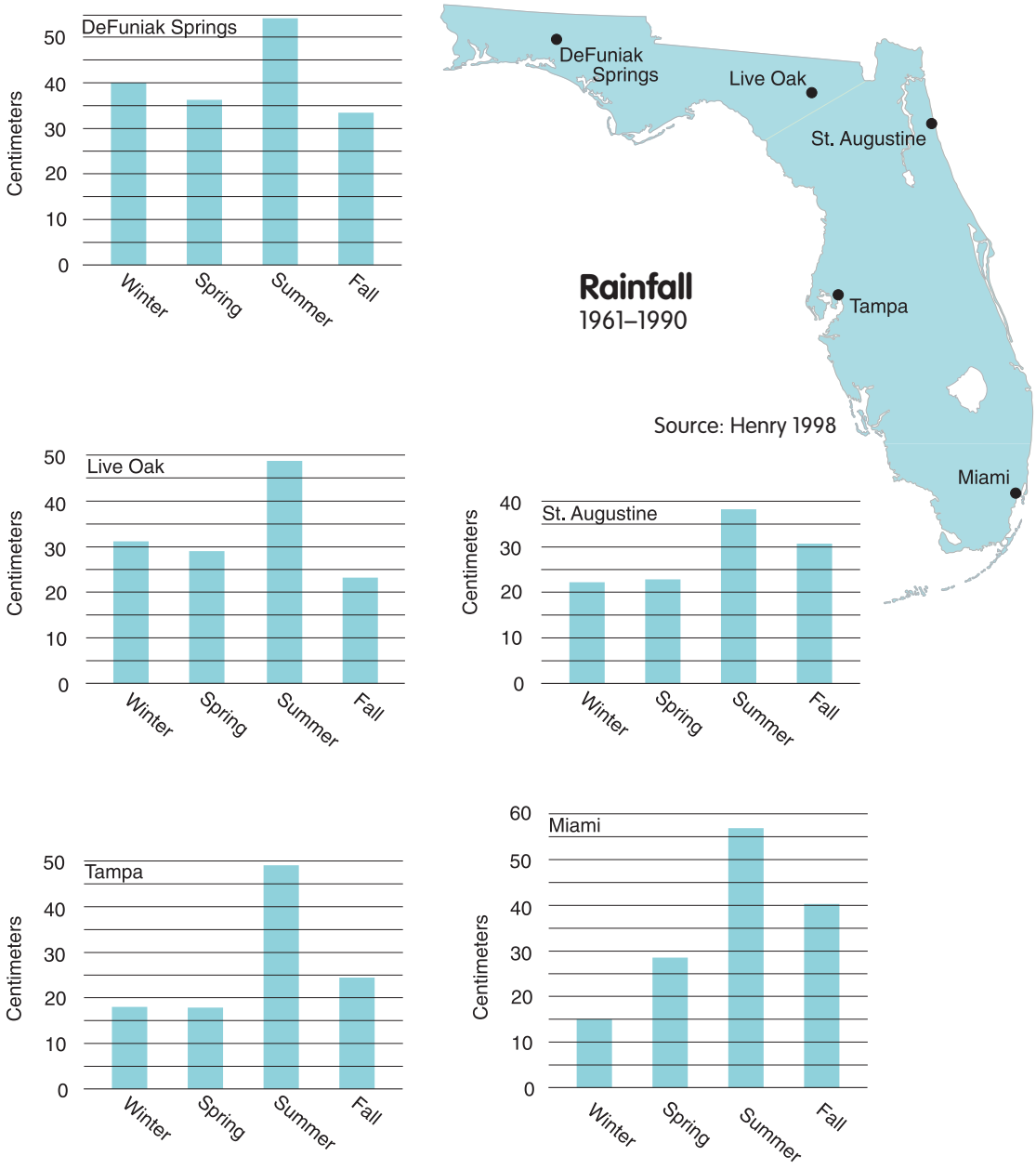
Florida's average rainfall varies greatly from year to year. However, averages in a state as large and as diverse as Florida may be misleading. In a year with "average" rainfall, one part of the state may have been very dry and another part may have been very wet!

In the Sunshine State, when it rains, it usually pours, and floods may result. Floods generally occur in winter and early spring in northern Florida from heavy rain accompanying cold fronts. In summer and fall, all of Florida is susceptible to flooding from thunderstorms and **hurricanes**. Human activities can create environments prone to flooding. Practices that remove soil and vegetation can increase an area's vulnerability to flooding. In northern Florida, flooding usually occurs along rivers. In southern Florida, flooding may occur in any low-lying area. Dikes, canals and other stormwater systems have been built in south and southwest Florida to help prevent flooding in developed areas.

Although Florida is one of the wettest states in the nation, it is still sometimes affected by **droughts** (extended periods of low rainfall). Moderate droughts occur frequently, and severe droughts occur in some part of the state about every six years. In the 1980s, a series of droughts occurred in the state. In 1988–89, rainfall in Key West was less than one-fifth the normal amount and in southwest Florida, groundwater levels were at a record low, causing many sinkholes to form. In June and July of 1998, extremely dry conditions in northern and central Florida resulted in more than 2,300 wildfires that consumed 200,000 hectares (500,000 acres), destroyed 368 houses and forced the evacuation of 130,000 people.

Rainfall deficits have continued since 1998 until the present (May 2001) throughout the state. These deficits would statistically be expected to occur only once every 100 to 200 years. The flow of the Apalachicola River and the depth of Lake Okeechobee have dropped to all-time lows. The St. Johns River Water Management District has experienced vast fluctuations in rainfall levels from one end of the district to the other. Calendar year 2000 was the driest on record (since 1915) in the Southwest Florida Water Management District. In some parts of the Southwest Florida Water Management District, drought conditions have increased the potential for sinkhole development, water quality problems and drying up of private wells.

During droughts, when the level of fresh water in the ground is lowered, salt water may move into freshwater portions of aquifers in a process known as **saltwater intrusion**. Because droughts reduce recharge, they can have a major



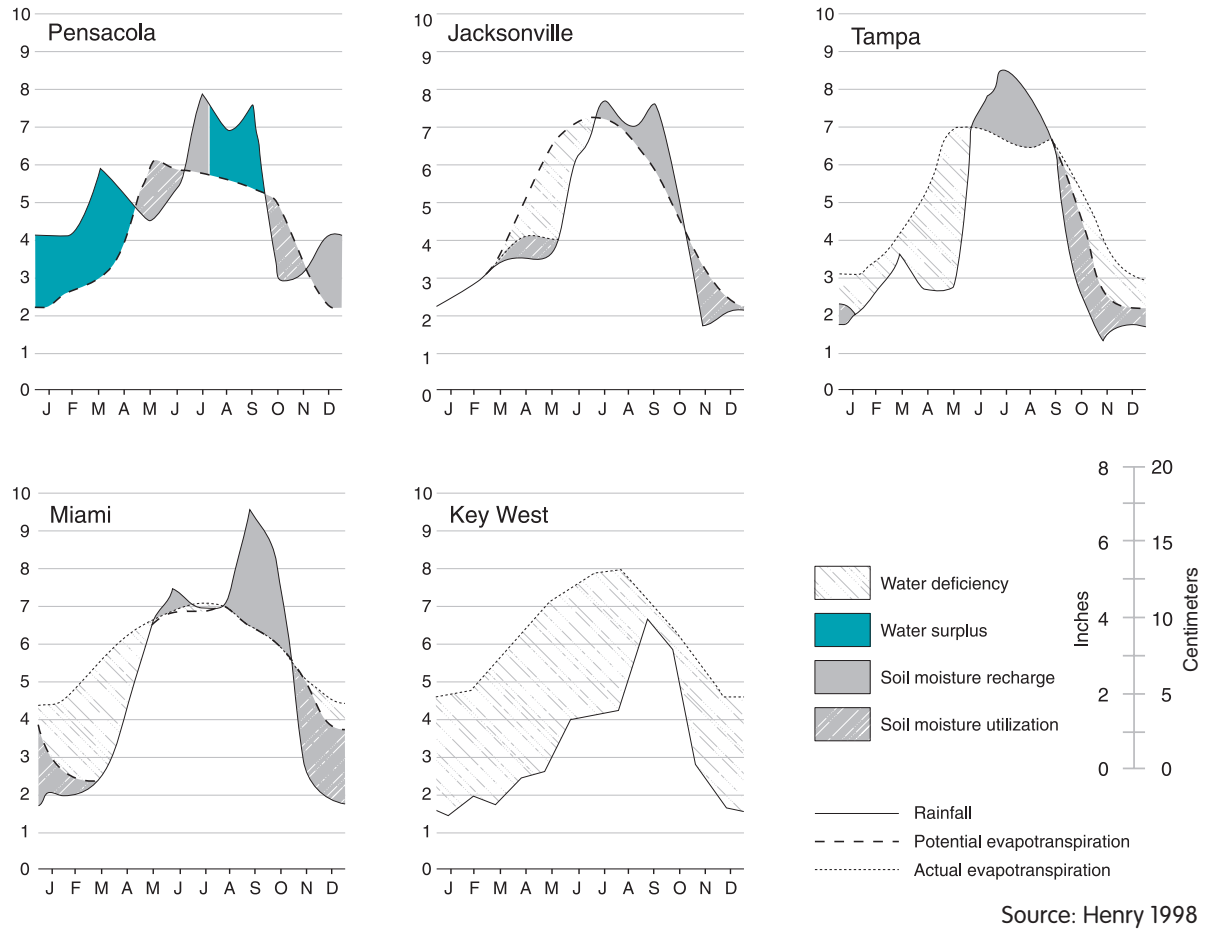
Throughout Florida, summer is the wettest season as a result of nearly daily thunderstorms. Hurricanes may also bring large amounts of rain. Winter and spring are the driest seasons in south Florida. Preceding cold fronts, significant amounts of rain usually fall in the Panhandle and north-central Florida during the winter.

impact on our underground water supply. Since salt water is heavier than fresh water, it occupies the lower portions of the aquifer. If the freshwater level is lowered by pumping and not replaced by recharge, salt water can flow in or rise up and contaminate underground freshwater supplies.

STORMS

Florida's peninsular shape, converging sea breezes, position relative to the Atlantic high pressure system, and tropical and subtropical location make it an ideal spawning ground for thunderstorms. Peninsular Florida is the thunderstorm capital of North America. "Tampa" may come from

Monthly Water Budgets



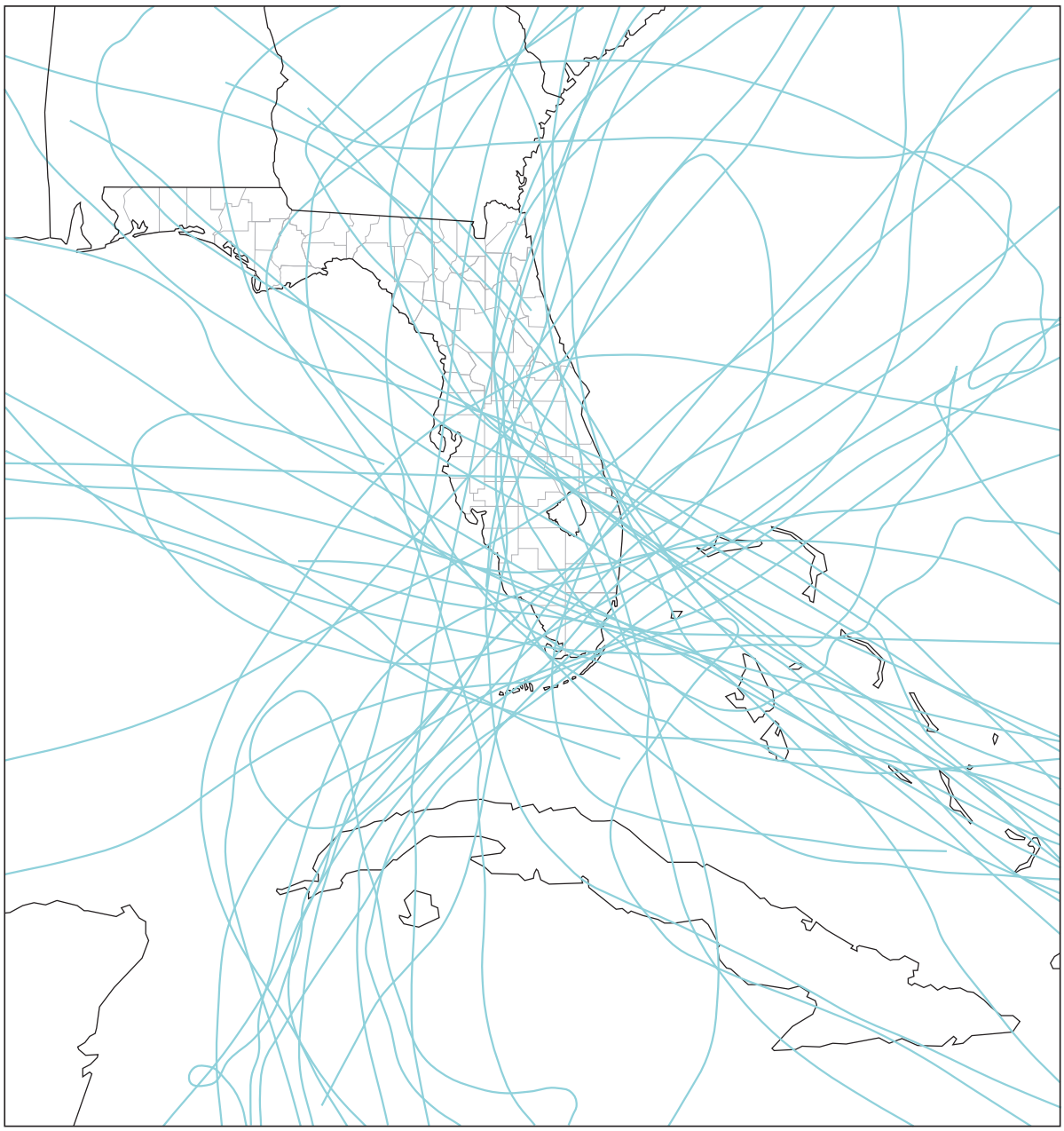
Source: Henry 1998

Hydrologists calculate **water budgets**, formulas used by hydrologists to determine water surpluses and deficits in an area, to help determine where and when these surpluses and deficits are most likely to occur. This knowledge is essential for planning and management. Floods may occur during times of surpluses, and water shortages may occur during times of deficits, particularly in high population areas. Irrigation of crops is usually necessary during periods of water deficits. In Florida, a water deficiency exists throughout the year in Key West. To meet its freshwater needs, Key West depends on either water pumped from the mainland or desalination. In the peninsula, deficits are common in winter and spring. Water deficits rarely occur in the Panhandle, but floods may occur during times of surpluses, particularly during the winter.

an Indian word meaning "stick of fire" (Henry, Portier and Coyne 1994) and is often referred to as the lightning capital of the United States. The Gulf coast from Tampa to Ft. Myers is one end of a lightning belt that stretches across the state to Daytona Beach and Cape Kennedy. Over 200 hours of thunderstorms occur each year in southwestern Florida.

Florida is also susceptible to hurricanes and **tornadoes**. Nearly 40 percent of all hurricanes that have made landfall in the United States have hit Florida. The most common points of landfall are in the Panhandle and along the southern portion of the peninsula. Hurricanes typically bring from 12 to 30 centimeters (5 to 12 inches) of rain, but have brought as much as

Hurricane Tracks
1886–1996

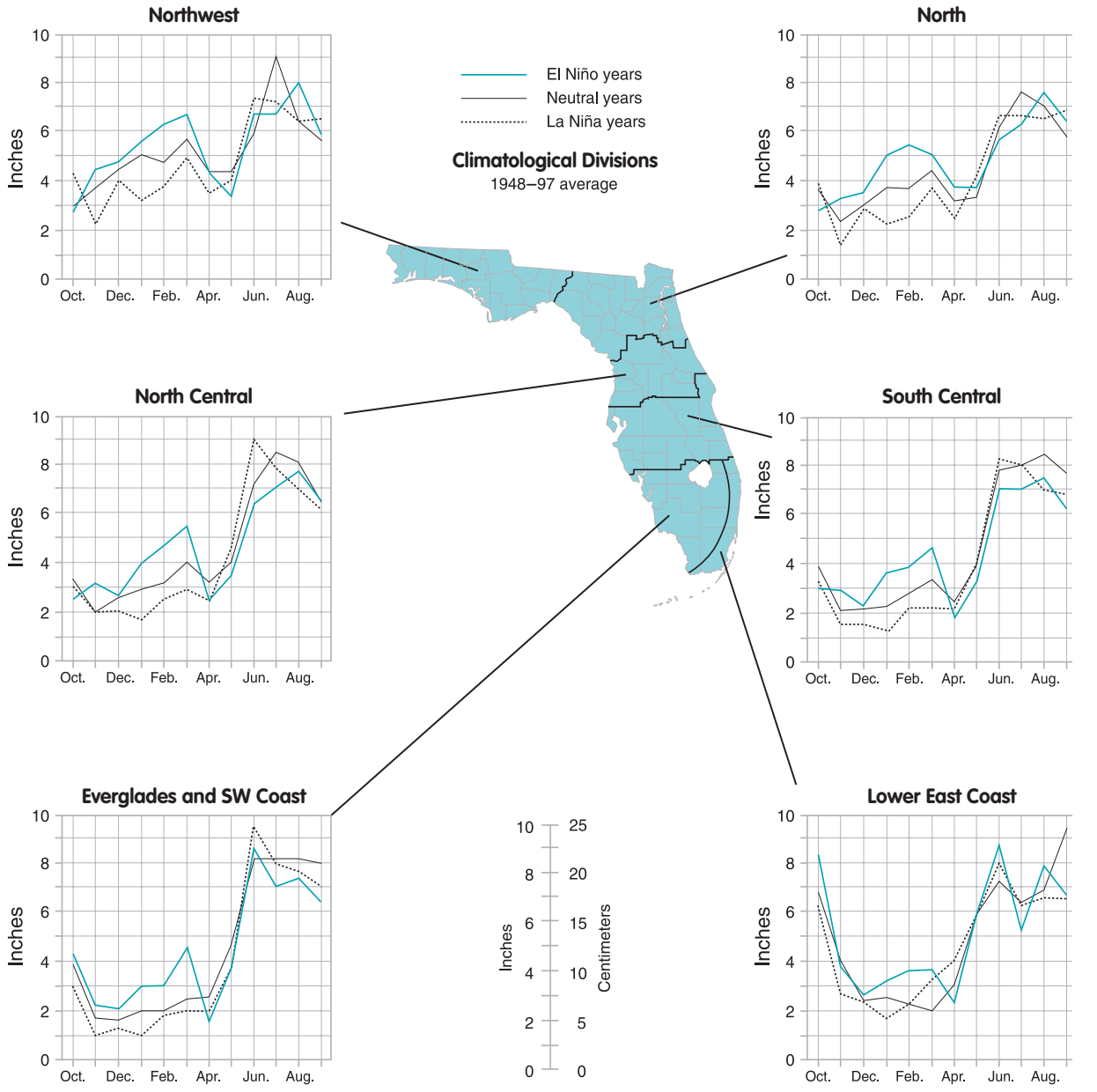


Source: Henry 1998

98 centimeters (38.7 inches) or as little as 1 centimeter (0.5 inches) (Henry 1998). South Florida was spared severe hurricanes from 1965 until 1992, when Andrew crossed southern Dade County, causing 26 deaths and over $3 billion in damages.

Florida also suffers from tornado damage, averaging 45 tornadoes each year. In Florida, tornadoes develop under four conditions: along the squall line ahead of an advancing cold front, along the squall line where masses of warm air converge, in isolated local summer thunderstorms, and within feeder bands associated with hurricanes (Winsberg 1990). Numerous water spouts that are in essence "mini-tornadoes" also occur.

Effects of El Niño



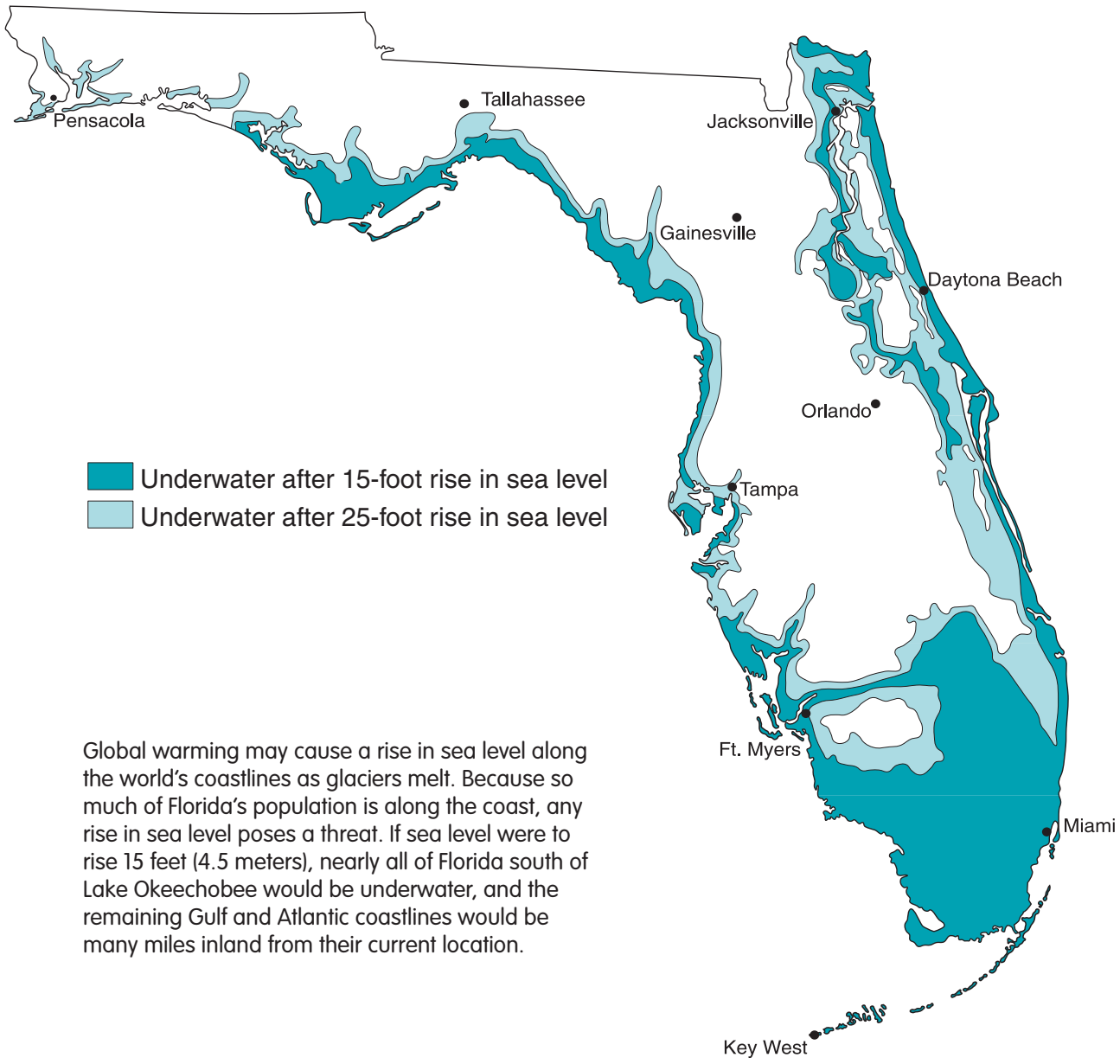
Source: Florida Consortium 1999

The Global Picture

EL NIÑO AND LA NIÑA

Florida's climate is strongly influenced by the temperatures of the Atlantic and Pacific oceans (Henry 1998). When the temperature of the Atlantic near the equator is higher than normal, less rain falls on Florida. This is a result of changing wind patterns that bring less moisture over Florida from the Gulf of Mexico.

Even more of an influence on Florida's weather are El Niño and La Niña, phenomena that occur in the Pacific Ocean off the coast of Peru. **El Niño** is an unseasonably warm ocean current that generally occurs every 3 to 7 years and lasts an average of about a year to 15 months.



Global warming may cause a rise in sea level along the world's coastlines as glaciers melt. Because so much of Florida's population is along the coast, any rise in sea level poses a threat. If sea level were to rise 15 feet (4.5 meters), nearly all of Florida south of Lake Okeechobee would be underwater, and the remaining Gulf and Atlantic coastlines would be many miles inland from their current location.

Source: Lane 1994

Peruvian fishermen first identified the event and named it El Niño after the Christ Child because it appeared off their coast around Christmas. Scientists do not fully understand this phenomenon. It begins when Pacific trade winds become weak and the top layer of the eastern Pacific gets warmer and warmer. The mass of clouds created by the warm water is carried eastward by the subtropical jet stream. **La Niña** (also sometimes called El Viejo) is the opposite of El Niño. La Niña occurs when stronger than normal trade winds stir up cooler water from the ocean depths.

El Niño years bring greater than normal amounts of rainfall to Florida in the winter than La Niña or neutral years, as well as more intense and frequent storms from the Gulf of Mexico. La Niña years bring less winter rainfall. Hurricanes, which originate in the Atlantic, are less frequent during El Niño years than during La Niña or neutral years.

By monitoring the Pacific Ocean west of Peru, scientists can now forecast El Niño and La Niña

(Florida Consortium 1999). This knowledge is critical to agriculture, forestry and emergency management. Winter vegetables and fruits are a big industry in Florida. Growers now know whether they are likely to face a wet or a dry growing season. Strawberry growers, for example, have learned to plant drought-tolerant varieties during La Niña years (Florida Consortium 1999). Dry La Niña winters may mean greater risk of forest fires in the normally dry spring. During El Niño years, although winters are wetter than normal, springs tend to be drier than normal in many parts of the state. These conditions may result in fires in early summer, as occurred in June 1998. Knowledge of La Niña helps emergency managers plan in advance for a hurricane season that will probably be more active than normal.

GLOBAL WARMING

In January 2001, over 700 scientists from more than 100 countries met in Shanghai, China, to discuss world climate change. They reviewed the data and agreed that the average global surface temperature has risen by 0.6 degrees centigrade over the twentieth century, and the sea level has risen between 0.1 and 0.2 meters. They predict temperatures will rise between 1.0 and 3.5 degrees centigrade over the coming century, causing more frequent floods and droughts, rising oceans and expansion of temperate climates northward. The group concluded that most of the warming observed over the last 50 years is attributable to human activities, specifically burning of fossil fuels such as coal and oil.

Although global warming is not accepted by the entire scientific community, some scientists predict that **global warming** will impact several aspects of Florida's climate (Henry 1998). While global rainfall levels are expected to increase, rainfall in Florida is expected to decrease as temperatures rise. According to some researchers, reduced rainfall and fewer winter storms reaching Florida would result from a predicted northward shift of the jet stream. Another study, however, indicated that summer rainfall would increase, particularly in the Panhandle. Droughts may also be more severe if temperatures rise, because rainfall would likely be more variable. Will the frequency and intensity of hurricanes reaching Florida increase with global warming? Early studies indicated that Florida might experience more frequent and more intense hurricanes in a warmer world, but more recent studies indicate that the threat from hurricanes will not likely increase significantly in the near future (Henry 1998).

Conclusion

Water is basic to all life on Earth. "Living things depend on water but water does not depend on living things. It has a life of its own" (Pielou 1998:x). The hydrologic cycle continues regardless of the activities of the millions of life forms it nourishes. Rain falls or fails to fall, rivers flow to the sea, snow falls and lakes freeze, hurricanes form over the warm seas, water seeps through the soil to replenish aquifers.

Today, humans have spread throughout the globe and have the power to influence the waters of the world on a scale unprecedented in our history. Burning of fossil fuels is contributing to global warming, which is predicted to bring more rain to some parts of the world and less to others. In many places, aquifers, rivers and lakes are being depleted and polluted. The water now on Earth is essentially all the water we will ever have. Yes, water is magic. It is up to us to respect and protect it.