Section 12.3

### Objectives

- **State** the importance of accurate weather data.
- **Summarize** the instruments used to collect weather data from Earth's surface.
- **Analyze** the strengths and weaknesses of weather radar and weather satellites.

### Review Vocabulary

**temperature:** the measurement of how rapidly or slowly particles move

### New Vocabulary

thermometer
barometer
anemometer
hygrometer
radiosonde
Doppler effect

# Gathering Weather Data

**MAIN Idea Accurate measurements of atmospheric properties are a critical part of weather analysis and prediction.**

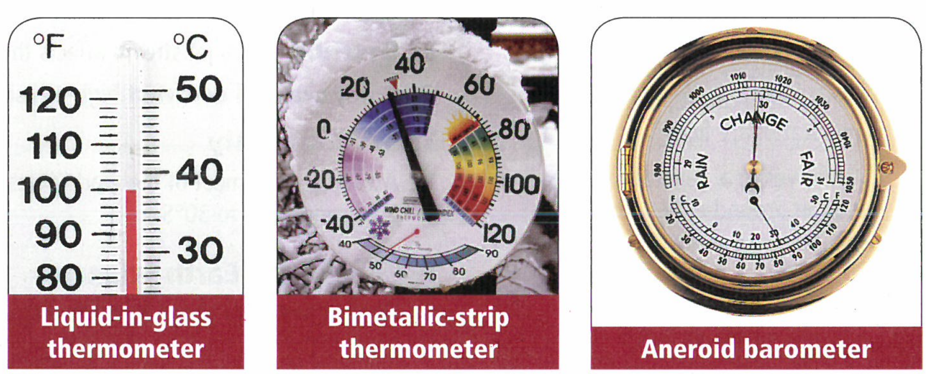
**Real-World Reading Link** Before a doctor can make a diagnosis, he or she must accurately assess the patient's state of health. This usually includes measuring body temperature and blood pressure. Similarly, in order to forecast the weather, meteorologists must have accurate measurements of the atmosphere.

## Data from Earth's Surface

Meteorologists measure atmospheric conditions, such as temperature, air pressure, wind speed, and relative humidity. The quality of the data is critical for complete weather analysis and precise predictions. Two important factors in weather forecasting are the accuracy of the data and the amount of available data.

**Temperature and air pressure** A **thermometer,** shown in **Figure 12.10,** measures temperature using either the Fahrenheit or Celsius scale. Thermometers in most homes are liquid-in-glass or bimetallic-strip thermometers. Liquid-in-glass thermometers contain a column of either mercury or alcohol sealed in a glass tube. The liquid expands when heated, causing the column to rise, and contracts when it cools, causing the column to fall. A bimetallic-strip thermometer has a dial with a pointer. It contains a strip of metal made from two different metals that expand at different rates when heated. The strip is long and coiled into a spiral, making it more sensitive to temperature changes.

A **barometer** measures air pressure. Some barometers have a column of mercury in a glass tube. One end of the tube is submerged in an open container of mercury. Changes in air pressure change the height of the column. Another type of barometer is an aneroid barometer, shown in **Figure 12.10.** It has a sealed, metal chamber with flexible sides. Most of the air is removed, so the chamber contracts or expands with changes in air pressure. A system of levers connects the chamber to a pointer on a dial.




■ **Figure 12.10** Thermometers and barometers are common weather instruments.

**Wind speed and relative humidity** An **anemometer** (a nuh MAH muh tur), shown in **Figure 12.11,** measures wind speed. The simplest type of anemometer has three or four cupped arms, positioned at equal angles from each other, that rotate as the wind blows. The wind's speed can be calculated using the number of revolutions of the cups over a given time. Some anemometers also have a wind vane that shows the direction of the wind.

A **hygrometer** (hi GRAH muh tur), such as the one in **Figure 12.11,** measures humidity. This type of hygrometer has wet-bulb and dry-bulb thermometers and requires a conversion table to determine relative humidity. When water evaporates from the wet bulb, the bulb cools. The temperatures of the two thermometers are read at the same time, and the difference between them is calculated. The relative humidity table lists the specific relative humidity for the difference between the thermometers.

**Reading Check** **Analyze** the relationship between the amount of moisture in air and the temperature of the wet bulb in a hygrometer.



**Figure 12.11** Anemometers are used to measure wind speed based on the rotation of the cups as the wind blows. Hygrometers measure humidity using techniques such as finding the temperature difference between the wet bulb and the dry bulb.

## Automated Surface Observing System

Meteorologists need a true "snapshot" of the atmosphere at one particular moment to develop an accurate forecast. To obtain this, meteorologists analyze and interpret data gathered at the same time from weather instruments at many different locations. Coordinating the collection of this data was a complicated process until late in the twentieth century. With the development of reliable automated sensors and computer technology, instantaneously collecting and broadcasting accurate weather-related data became possible.

In the United States, the National Weather Service (NWS), the Federal Aviation Administration, and the Department of Defense jointly established a surface-weather observation network known as the Automated Surface Observing System (ASOS). It gathers data in a consistent manner, 24 hours a day, every day. It began operating in the 1990s and more than doubled the number of full-time observation sites, such as the one shown in **Figure 12.12.** ASOS provides essential weather data for aviation, weather forecasting, and weather-related research.

**Figure 12.12** This weather station in the United Kingdom consists of several instruments that measure atmospheric conditions.

■ **Figure 12.13** Radiosondes gather upper-level weather data such as air temperature, pressure, and humidity.

## Data from the Upper Atmosphere

While surface-weather data are important, the weather is largely the result of changes that take place high in the troposphere. To make accurate forecasts, meteorologists must gather data at high altitudes, up to 30,000 m. This task is more difficult than gathering surface data, and it requires sophisticated technology.

An instrument used for gathering upper-atmospheric data is a **radiosonde** (RAY dee oh sahnd), shown in **Figure 12.13.** It consists of a package of sensors and a battery-powered radio transmitter. These are suspended from a balloon that is about 2 m in diameter and filled with helium or hydrogen. A radiosonde's sensors measure the air's temperature, pressure, and humidity. Radio signals constantly transmit these data to a ground station that tracks the radiosonde's movement. If a radiosonde also measures wind direction and speed, it is called a rawinsonde (RAY wuhn sahnd), **ra**dar + **win**d + radio**sonde**.

Tracking is a crucial component of upper-level observations. The system used since the 1980s has been replaced with one that uses Global Positioning System (GPS) and the latest computer technology. Meteorologists can determine wind speed and direction by tracking how fast and in what direction a rawinsonde moves. The various data are plotted on a chart that gives meteorologists a profile of the temperature, pressure, humidity, wind speed, and wind direction of a particular part of the atmosphere. Such charts are used to forecast atmospheric changes that affect surface weather.

**Reading Check** **Describe** the function of a radiosonde.

**VOCABULARY**

**ACADEMIC VOCABULARY**

**Compute (kuhm PYEWT)**
to perform mathematical operations
*Jane used a calculator to compute the answers for her math homework.*

## Weather Observation Systems

There are many surface and upper-level observation sites across the United States. However, data from these sites cannot be used to locate exactly where precipitation falls without the additional help of data from weather radars and weather satellites.

**Weather radar** A weather radar system detects specific locations of precipitation. The term *radar* stands for **ra**dio **d**etection **a**nd **r**anging. How does radar work? A radar system generates radio waves and transmits them through an antenna at the speed of light. Recall that radio waves are electromagnetic waves with wavelengths greater than $10^{-3}$ m. The transmitter is programmed to generate waves that only reflect from particles larger than a specific size. For example, when the radio waves encounter raindrops, some of the waves scatter. Because an antenna cannot send and receive signals at the same time, radars send a pulse and wait for the return before another pulse is sent. An amplifier increases the received wave signals, and then a computer processes and displays them on a monitor. From these data, the distance to precipitation and its location relative to the receiving antenna.

**Doppler weather radar** You have probably noticed that the pitch produced by the horn of an approaching car gets higher as it comes closer to you and lower as it passes and moves away from you. This sound phenomenon is called the Doppler effect. The **Doppler effect** is the change in pitch or frequency that occurs due to the relative motion of a wave, such as sound or light, as it comes toward or goes away from an observer.

The NWS uses Weather Surveillance Radar-1988 Doppler (WSR-88D), shown in **Figure 12.14,** based on the Doppler effect of moving waves. Analysis of Doppler radar data can be used to determine the speed at which precipitation moves toward or away from a radar station. Because the movement of precipitation is caused by wind, Doppler radar can also provide a good estimation of the wind speeds associated with precipitation areas, including those with severe weather, such as thunderstorms and tornados. The ability to measure wind speeds gives Doppler radar a distinct advantage over conventional weather radar systems.

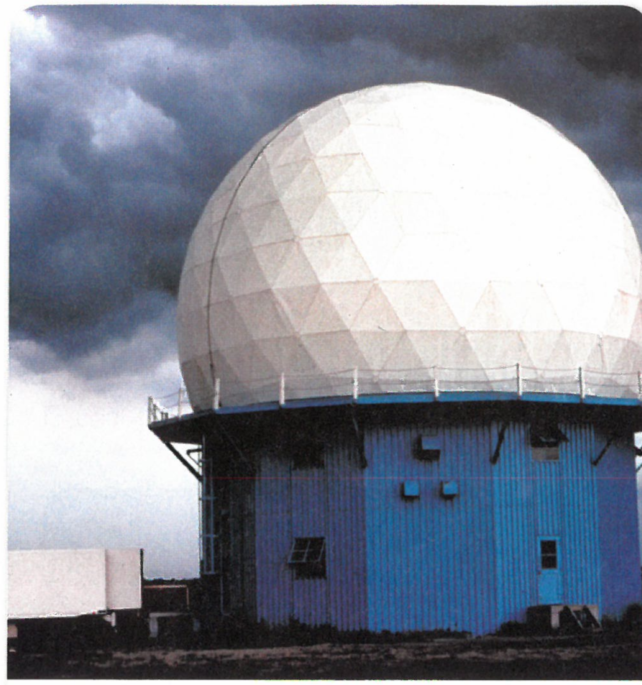


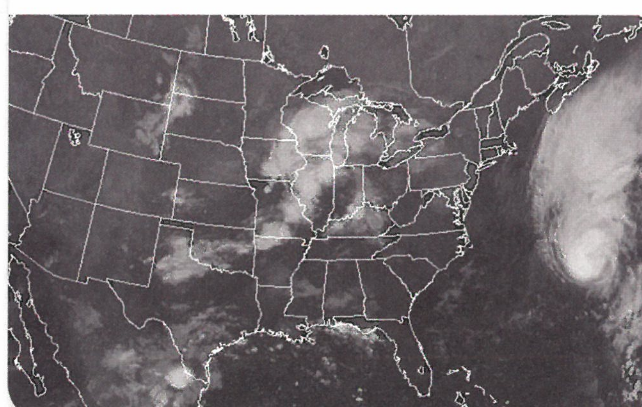
**Figure 12.14** Norman, Oklahoma, was the site of the first Doppler radar installation.
**Relate** *the importance of this location to severe weather conditions.*

**Weather satellites** In addition to communications, one of the main uses of satellites orbiting Earth is to observe weather. Cameras mounted aboard a weather satellite take photos of Earth at regular intervals. A weather satellite can use infrared, visible-light, or water-vapor imagery to observe the atmosphere.

**Infrared imagery** Some weather satellites use infrared imagery to make observations at night. Objects radiate thermal energy at slightly different frequencies. Infrared imagery detects these different frequencies, which enables meteorologists to map either cloud cover or surface temperatures. Different frequencies are distinguishable in an infrared image, as shown in **Figure 12.15.**

As you learned in Chapter 11, clouds form at different altitudes and have different temperatures. Using infrared imagery, meteorologists can determine the cloud's temperature, its type, and its altitude. Infrared imagery is useful especially in detecting strong thunderstorms that develop and reach high altitudes. Consequently, they appear as very cold areas on an infrared image. Because the strength of a thunderstorm is related to the altitude that it reaches, infrared imagery can be used to establish a storm's potential to produce severe weather.

**Figure 12.15** This infrared image shows cloud cover across most of the United States.



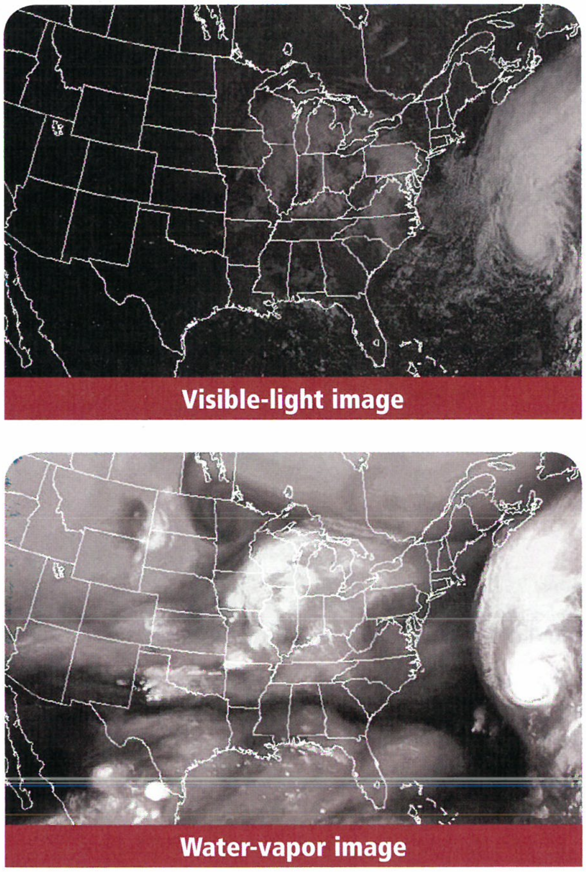



**Figure 12.16** These images were taken at the same time as the one in **Figure 12.15.** Each type of image shows different atmospheric characteristics. Together, they help meteorologists accurately analyze and predict weather.

**Visible-light imagery** Some satellites use cameras that require visible light to photograph Earth. These digital photos, like the one in **Figure 12.16,** are sent back to ground stations, and their data are plotted on maps. Unlike weather radar, which tracks precipitation but not clouds, satellites track clouds but not necessarily precipitation. By combining radar and visible imagery data, meteorologists can determine where both clouds and precipitation are occurring.

**Water-vapor imagery** Another type of satellite imagery that is useful in weather analysis and forecasting is called water-vapor imagery, also shown in **Figure 12.16.** Water vapor is an invisible gas and cannot be photographed directly, but it absorbs and emits infrared radiation at certain wavelengths. Many weather satellites have sensors that are able to provide a measure of the amount of water vapor present in the atmosphere.

Water-vapor imagery is a valuable tool for weather analysis and prediction because it shows moisture in the atmosphere, not just cloud patterns. Because air currents that guide weather systems are often well defined by trails of water vapor, meteorologists can closely monitor the development and change in storm systems even when clouds are not present.

## Section 12.3 Assessment

### Section Summary

- To make accurate weather forecasts, meteorologists analyze and interpret data gathered from Earth's surface by weather instruments.
- A radiosonde collects upper-atmospheric data.
- Doppler radar locates where precipitation occurs.
- Weather satellites use infrared, visible-light, or water-vapor imagery to observe and monitor changing weather conditions on Earth.

### Understand Main Ideas

1. MAIN Idea **Identify** two important factors in collecting and analyzing weather data in the United States.
2. **Compare and contrast** methods for obtaining data from Earth's surface and Earth's upper atmosphere.
3. **State** the main advantage of Doppler radar over conventional weather radar.
4. **Summarize** the three kinds of weather satellite imagery using a graphic organizer.

### Think Critically

5. **Predict** whether you would expect weather forecasts to be more accurate for the state of Kansas or a remote Caribbean island, based on what you know about weather observation systems. Explain.

### WRITING in Earth Science

6. Write a newspaper article about the use of water-vapor imagery to detect water on the planet Mars.



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