Air Masses

Before we begin to study weather systems, we should understand the nature and significance of air masses. In themselves, air masses provide a straightforward way of looking at the weather. An **air mass** is a large body of air, at times subcontinental in size, that moves over Earth's surface with distinguishable characteristics. An air mass is relatively homogeneous in temperature and humidity; that is, at approximately the same altitude within the air mass, the temperature and humidity will be similar. As a result of this temperature and moisture uniformity, the density of air will be much the same throughout any one level within an air mass. Of course, because an air mass may extend over 20 or 30 degrees of latitude, we can expect some slight variations due to changes in sun angle and its corresponding insolation, which are significant over that distance. Changes caused by contact with differing land and ocean surfaces also affect the characteristics of air masses.

The similar characteristics of temperature and humidity within an air mass are determined by the nature of its **source region**—the place where the air mass originates. Only a few areas on Earth make good source regions. For the air mass to have similar characteristics throughout, the source region must have a nearly homogeneous surface. For example, it can be a desert, an ice sheet, or an ocean body, but not a combination of surfaces. In addition, the air mass must have sufficient time to acquire the characteristics of the source region. Hence, gently settling, slowly diverging air will mimic a source region, whereas converging, rising air will not.

Air masses are identified by a simple letter code. The first is always a lowercase letter. There are two choices: The letter *m,* for maritime, means the air mass originates over the sea and is therefore relatively moist. The letter *c,* for continental, means the air mass originates over land and is therefore relatively dry. The second letter is always a capital. These help to locate the latitude of the source region. *E* stands for Equatorial; this air is very warm. The letter *T* identifies a Tropical origin and is therefore warm air. A *P* represents Polar; this air can be quite cold. Lastly, an *A* identifies Arctic air, which is very cold. These six letters can be combined to give us the classification of air masses first described in 1928 and still used today: **Maritime Equatorial (*mE*), Maritime Tropical (*mT*), Continental Tropical (*cT*), Continental Polar (*cP*), Maritime Polar (*mP*),** and **Continental Arctic (*cA*).** These six types are described more fully in Table 7.1. From now on, we will use the symbols rather than the full names as we discuss each type of air mass.

Modification and Stability of Air Masses

As a result of the general circulation patterns within the atmosphere, air masses do not remain stationary over their source regions indefinitely. When an air mass begins to move over Earth's surface along a path known as a trajectory, for the most part it retains its distinct and homogeneous characteristics. However, modification does occur as the air mass gains or loses some of its thermal energy and moisture content to the surface below. Although this modification is generally slight, the gain or loss of thermal energy can make an air mass more stable or unstable.

An air mass is further classified by whether it is warmer or colder than the surface over which it travels because this has a bearing on its stability. If an air mass is colder than the surface over which it passes, then the surface will heat the air mass from below. This will in turn increase the environmental lapse rate, enhancing the prospect of instability. To describe such a situation, the letter *k* (from German: *kalt,* cold) is added to the other letters that symbolize the air mass. For example, an *mT* air mass originating over the Gulf of Mexico in summer that moves onshore over warmer land would be denoted *mTk*. Such an air mass is often unstable and can produce copious convective precipitation. On the other hand, this same *mT* air mass moving onshore during the winter would be warmer than the land surface. Consequently, the air mass would be cooled from below, decreasing its environmental lapse rate, which enhances the prospect of stability. We describe this situation with the letter *w* (from German: *warm,* warm), and the air mass would be denoted *mTw*. In this case, stratiform (lighter), not convective (heavier), precipitation is most likely.

The modification of air masses can also involve moisture content. For example, during the early-winter to midwinter seasons, cold, dry *cP* or *cA* air from Canada can move southeastward across the Great Lakes region. While passing over the lakes, this air mass can pick up moisture, thus increasing its humidity level. This modified *cP* or *cA* air reaches the frigid land on the leeward shores of the Great Lakes and precipitates, at times, large amounts of *lake-effect snows.* These snowfall areas may appear as *snow belts* or bands of snow, extending downwind from the lakes. The chances for lake-effect snow events diminish in late winter as the surfaces of the lakes freeze, thus cutting off the moisture supply to the air masses flowing across them.

North American Air Masses

Most of us are familiar with the weather in at least one region of the United States or Canada; therefore, in this chapter we will concentrate on the air masses of North America and their effects on weather. What we learn will be applicable to the rest of the world, and as we examine climate regions in some of the following chapters, we will be able to understand that weather everywhere is most often affected by the movements of air masses. Especially in middle-latitude regions, the majority of atmospheric disturbances result from the confrontations of different air masses.

Five types of air masses (*cA, cP, mP, mT,* and *cT*) influence the weather of North America, some more than others. Air masses assume characteristics of their source regions (● Fig. 7.1). Consequently, as the source regions change with the seasons, primarily because of changing insolation, the air masses also will vary.

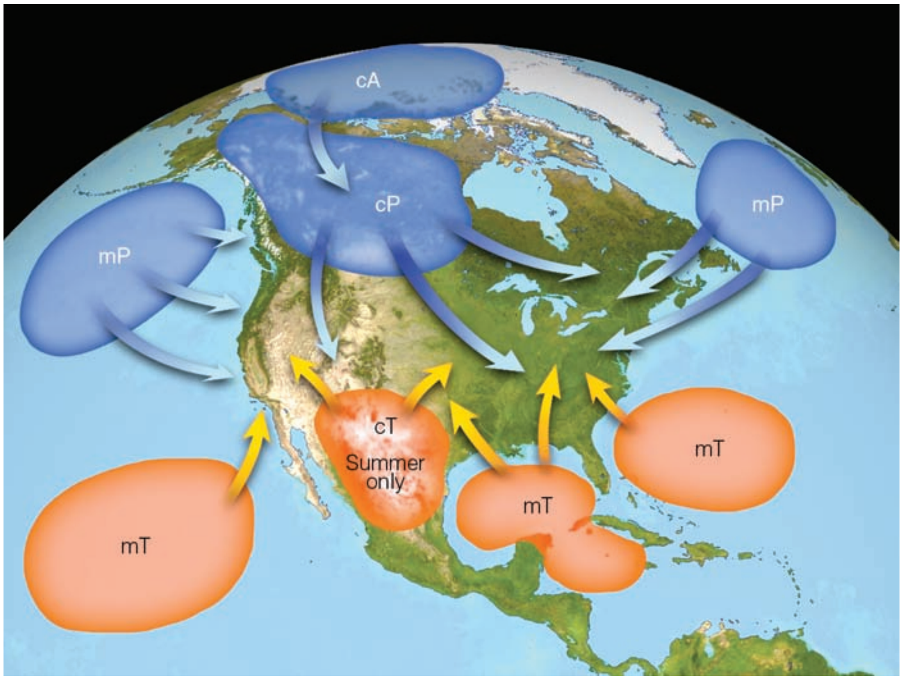
Continental Arctic Air Masses

The frigid, frozen surface of the Arctic Ocean and the land surface of northern Canada and Alaska serve as source regions for this air mass. It is extremely cold, very dry, and very stable. Though it will affect parts of Canada, even during the winter when this air mass is best developed, it seldom travels far enough south to affect the United States. However, on those few occasions when it does extend down into the midwestern and southeastern United States, its impact is awesome. Record-setting

TABLE 7.1
Types of Air Masses

Source	Region	Usual Characteristics at Source	Accompanying Weather
Maritime Equatorial (*mE*)	Equatorial oceans	Ascending air, very high	High temperature and humidity, heavy moisture content rainfall; never reaches the United States
Maritime Tropical (*mT*)	Tropical and subtropical oceans	Subsiding air; fairly stable but some instability on western side of oceans; warm and humid	High temperatures and humidity, cumulus clouds, convectional rain in summer; mild temperatures, overcast skies, fog, drizzle, and occasional snowfall in winter; heavy precipitation along *mT/cP* fronts in all seasons
Continental Tropical (*cT*)	Deserts and dry plateaus of subtropical latitudes	Subsiding air aloft; generally stable but some local instability at surface; hot and very dry	High temperatures, low humidity, clear skies, rare precipitation
Maritime Polar (*mP*)	Oceans between 40° and 60° latitude	Ascending air and general instability, especially in winter; mild and moist	Mild temperatures, high humidity; overcast skies and frequent fogs and precipitation, especially during winter; clear skies and fair weather common in summer; heavy orographic precipitation, including snow, in mountainous areas
Continental Polar (*cP*)	Plains and plateaus of subpolar and polar latitudes	Subsiding and stable air, especially in winter; cold and dry	Cool (summer) to very cold (winter) temperatures, low humidity; clear skies except along fronts; heavy precipitation, including winter snow, along *cP/mT* fronts
Continental Arctic (*cA*)	Arctic Ocean, Greenland, and Antarctica	Subsiding very stable air; very cold and very dry	Seldom reaches United States, but when it does, bitter cold, subzero temperatures, clear skies, often calm conditions

FIGURE 7.1
Source regions of North American air masses. Air mass movements import the temperature and moisture characteristics of these source regions into distant areas.
Use Table 7.1 and this figure to determine which air masses affect your location. Are there seasonal variations?



cold temperatures often result. If the *cA* air mass remains in the Midwest for an extended period, vegetation unaccustomed to the extreme cold can be severely damaged or killed.

Continental Polar Air Masses At its source in north-central North America, a *cP* air mass is cold, dry, and stable because it is warmer than the surface beneath it; the weather of a *cP* air mass is cold, crisp, and clear. Because there are no east–west landform barriers in North America, *cP* air can migrate south across Canada and the United States. A tongue of *cP* air can sometimes reach as far south as the Gulf of Mexico or Florida. When winter *cP* air extends into the United States, its temperature and humidity are raised only slightly. The movement of such an air mass into the Midwest and South brings with it a cold wave characterized by colder-than-average temperatures and clear, dry air and can cause freezing temperatures as far south as Florida and Texas.

The general westerly direction of atmospheric circulation in the middle latitudes rarely allows a *cP* air mass to break through the great western mountain ranges to the West

Coast of the United States. When such an air mass does reach the Washington, Oregon, and California coasts, it brings with it unusual freezing temperatures that do great damage to agriculture.

Maritime Polar Air Masses

During winter months, the oceans tend to be warmer than the land, so an *mP* air mass tends to be warmer than its counterpart on land (the *cP* air mass). Much *mP* air is originally cold, dry *cP* air that has moved to a position over the ocean. There, it is modified by the warmer water and collects heat and moisture. Thus, *mP* air is cold (although not as cold as *cP* air) and damp, with a tendency toward instability. The northern Pacific Ocean serves as the source region for *mP* air masses, which, because of the general westerly circulation of the atmosphere in the middle latitudes, affect the weather of the northwestern United States and southwestern Canada. When this *mP* air meets an uplift mechanism (such as a mass of colder, denser air or coastal mountain ranges), the result is usually very cloudy weather with a great deal of precipitation. An *mP* air mass may still be the source of many midwestern snowstorms even after crossing the western mountain ranges.

Generally, an *mP* air mass that develops over the northern Atlantic Ocean does not affect the weather of the United States because such an air mass tends to flow eastward toward Europe. However, on some occasions, there may be a reversal of the dominant wind direction accompanying a low pressure system, and New England can be made miserable by the cool, damp winds, rain, and snow of a weather system called a *nor'easter.* A nor'easter may, at times, bring serious winter storm conditions to our New England states.

Maritime Tropical Air Masses

The Gulf of Mexico and subtropical Atlantic and Pacific Oceans serve as source regions for *mT* air masses that have a great influence on the weather of the United States and at times southeastern Canada. During winter, the waters are warm, and the air above is warm, and moist. As the warm, moist air moves northward up the Mississippi lowlands, it travels over increasingly cooler land surfaces. The lower layers of air are chilled, and dense advection fog often results. When it reaches the *cP* air migrating southward from Canada, the warm *mT* air is forced to rise over the colder, drier *cP* air, and significant precipitation can occur.

The longer days and more intense insolation of summer months modify an *mT* air mass at the source region by increasing its temperature and moisture content. However, during summer, the land is warmer than the nearby waters, and as the *mT* air mass moves onto the land, the instability of the air mass increases. This air mass is a factor in the formation of great thunderstorms and convective precipitation on hot, humid days, and it is also responsible for much of the hot, humid weather of the southeastern and eastern United States.

Maritime tropical air masses also form over the Pacific Ocean in the subtropical latitudes. These air masses tend to be slightly cooler than those that form over the Gulf of Mexico and the Atlantic, partly because of their passage over the cooler California Current. A Pacific *mT* air mass is also more stable because of the strong subsidence associated with the eastern portion of the Pacific subtropical high. This air mass contributes to the dry summers of Southern California and occasionally brings moisture in winter as it rises over the mountains of the Pacific Coast.

Continental Tropical Air Masses

A fifth type of air mass may affect North America, but it is the least important to the weather of the United States and Canada. This is the *cT* air mass that develops over large, homogeneous land surfaces in the subtropics. The Sahara Desert of North Africa is a prime example of a source region for this type of air mass. The weather typical of the *cT* air mass is usually very hot and dry, with clear skies and major heating from the sun during daytime.

In North America, there is little land in the correct latitudes to serve as a source region for a *cT* air mass of any significant proportion. A small *cT* air mass can form over the deserts of the southwestern United States and central Mexico in the summer. In the source region, a *cT* air mass provides hot, dry, clear weather. When it moves eastward, however, it is usually greatly modified as it comes in contact with larger and stronger air masses of different temperature, humidity, and density values. At times, *cT* air from Mexico and Texas meets with *mT* air from the Gulf of Mexico. This boundary is known as a *dry line.* Here, the drier air is denser and will lift the moister air over it. This mechanism of uplift may act as a trigger for precipitation episodes and perhaps thunderstorm activity.

Fronts

We have seen that air masses migrate with the general circulation of the atmosphere. Over the United States, which is influenced primarily by the westerlies, there is a general eastward flow of the air masses. In addition, air masses tend to diverge from areas of high pressure and converge toward areas of low pressure. This tendency means that the tropical and polar air masses, formed within systems of divergence, tend to flow toward areas of convergence within the United States. As previously noted, an important feature of an air mass is that it maintains the primary characteristics first imparted to it by its source region, although some slight modification may occur during its migration.

When air masses differ, they do so primarily in their temperature and in their moisture content, which in turn affect the air masses' density and atmospheric pressure. As we saw in Chapter 6, when different air masses come together, they do not mix easily but instead come in contact along sloping boundaries called *fronts.* Although usually depicted on maps as a one-dimensional boundary line separating two different air masses, a front is actually a three-dimensional surface with length, width, and height. To emphasize this concept, a front is sometimes referred to as a **surface of discontinuity.** This surface of discontinuity is a zone that can cover an area from 2 to 3 kilometers (1–2 mi) wide to as wide as 150 kilometers (90 mi). Hence, it is more accurate to speak of a frontal zone rather than a frontal line.

The sloping surface of a front is created as the warmer and lighter of the two contrasting air masses is lifted or rises above the cooler and denser air mass. Such rising, known as *frontal uplift,* is a major source of precipitation in middle-latitude countries like the United States and Canada (as well as middle-latitude European and Asian countries) where contrasting air masses are most likely to converge.