areas of the world, at a size and scale convenient for navigation by moderate speed aircraft. They are produced at a scale of 1:1,000,000 (1 inch = 13.7 nautical miles or approximately 16 statute miles). These charts are similar to sectional charts and the symbols are the same except there is less detail due to the smaller scale. These charts are revised annually except several Alaskan charts and the Mexican/Caribbean charts which are revised every 2 years.

LATITUDE AND LONGITUDE (MERIDIANS AND PARALLELS)

The Equator is an imaginary circle equidistant from the poles of the Earth. Circles parallel to the Equator (lines running east and west) are parallels of latitude. They are used to measure degrees of latitude north or south of the Equator. The angular distance from the Equator to the pole is one-fourth of a circle or 90°. The 48 conterminous states of the United States are located between 25° and 49° N. latitude. The arrows in figure 14-2 labeled "LATITUDE" point to lines of latitude.

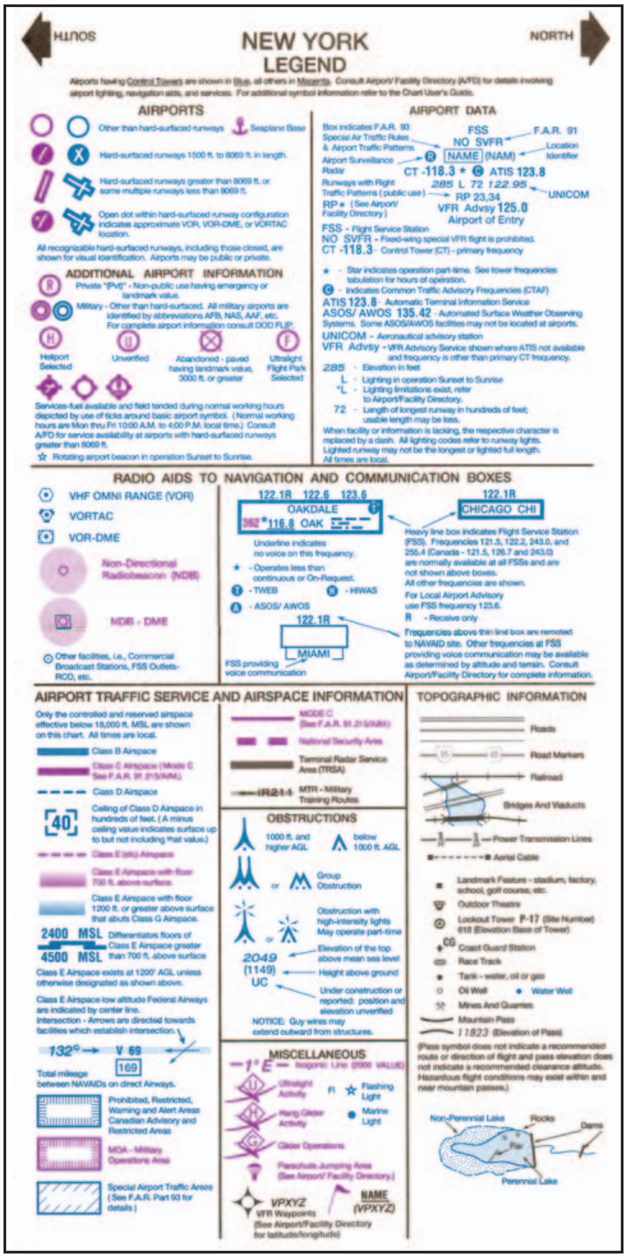

Figure 14-1. Sectional chart legend.

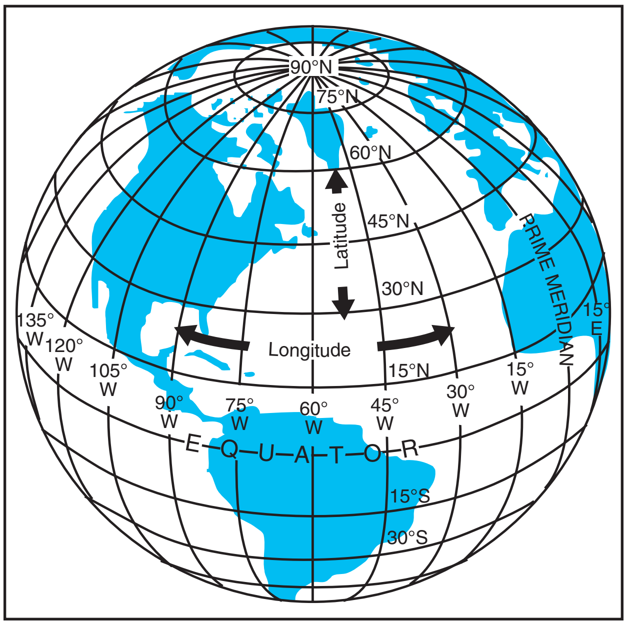

Figure 14-2. Meridians and parallels—the basis of measuring time, distance, and direction.

Meridians of longitude are drawn from the North Pole to the South Pole and are at right angles to the Equator. The "Prime Meridian" which passes through Greenwich, England, is used as the zero line from which measurements are made in degrees east and west to 180°. The 48 conterminous states of the United States are between 67° and 125° W. Longitude. The arrows in figure 14-2 labeled "LONGITUDE" point to lines of longitude.

Any specific geographical point can thus be located by reference to its longitude and latitude. Washington, DC for example, is approximately 39° N. latitude, 77° W. longitude. Chicago is approximately 42° N. latitude, 88° W. longitude.

TIME ZONES

The meridians are also useful for designating time zones. A day is defined as the time required for the Earth to make one complete rotation of 360°. Since the day is divided into 24 hours, the Earth revolves at the rate of 15° an hour. Noon is the time when the Sun is directly above a meridian; to the west of that meridian is morning, to the east is afternoon.

The standard practice is to establish a time zone for each 15° of longitude. This makes a difference of exactly 1 hour between each zone. In the United States, there are four time zones. The time zones are Eastern (75°), Central (90°), Mountain (105°), and Pacific (120°). The dividing lines are somewhat irregular because communities near the boundaries often find it more convenient to use time designations of neighboring communities or trade centers.

Figure 14-3 shows the time zones in the United States. When the Sun is directly above the 90th meridian, it is noon Central Standard Time. At the same time, it will be 1 p.m. Eastern Standard Time, 11 a.m. Mountain Standard Time, and 10 a.m. Pacific Standard Time. When "daylight saving" time is in effect, generally between the last Sunday in April and the last Sunday in October, the Sun is directly above the 75th meridian at noon, Central Daylight Time.

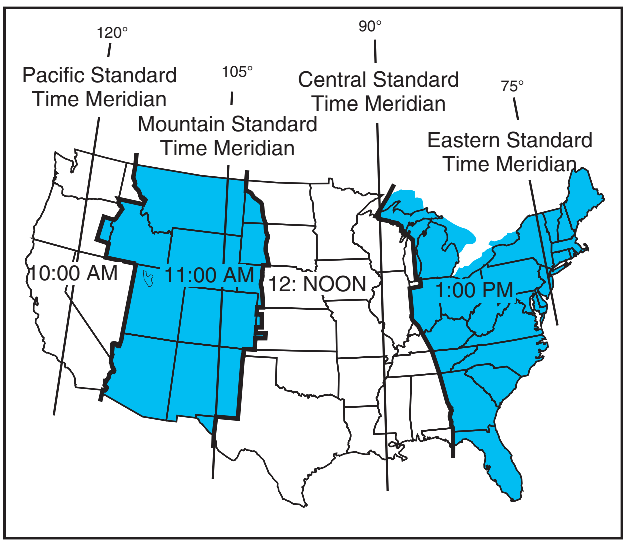

Figure 14-3. Time zones.

These time zone differences must be taken into account during long flights eastward—especially if the flight must be completed before dark. Remember, an hour is lost when flying eastward from one time zone to another, or perhaps even when flying from the western edge to the eastern edge of the same time zone. Determine the time of sunset at the destination by consulting the flight service stations (AFSS/FSS) or National Weather Service (NWS) and take this into account when planning an eastbound flight.

In most aviation operations, time is expressed in terms of the 24-hour clock. Air traffic control instructions, weather reports and broadcasts, and estimated times of arrival are all based on this system. For example: 9 a.m. is expressed as 0900, 1 p.m. is 1300, and 10 p.m. is 2200.

Because a pilot may cross several time zones during a flight, a standard time system has been adopted. It is called Universal Coordinated Time (UTC) and is often referred to as Zulu time. UTC is the time at the 0° line of longitude which passes through Greenwich, England. All of the time zones around the world are based on this reference. To convert to this time, a pilot should do the following:

Eastern Standard Time..........Add 5 hours

Central Standard Time..........Add 6 hours

Mountain Standard Time...... Add 7 hours

Pacific Standard Time.......... Add 8 hours

For daylight saving time, 1 hour should be subtracted from the calculated times.

MEASUREMENT OF DIRECTION

By using the meridians, direction from one point to another can be measured in degrees, in a clockwise direction from true north. To indicate a course to be followed in flight, draw a line on the chart from the point of departure to the destination and measure the angle which this line forms with a meridian. Direction is expressed in degrees, as shown by the compass rose in figure 14-4.

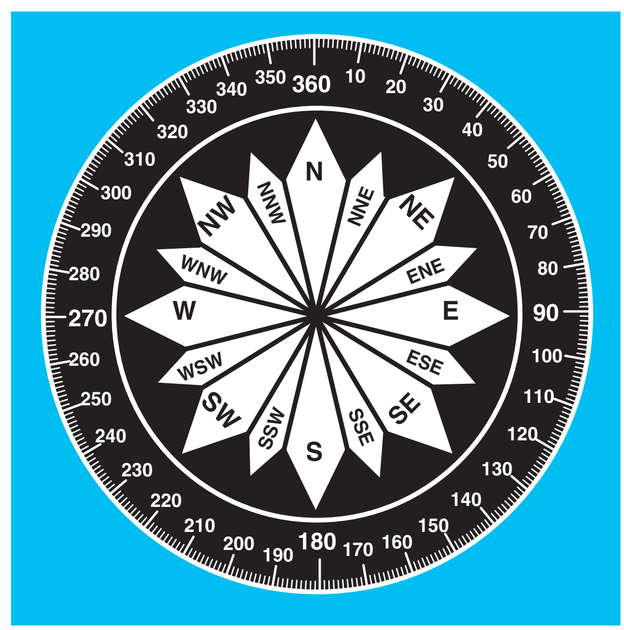

Figure 14-4. Compass rose.

Because meridians converge toward the poles, course measurement should be taken at a meridian near the midpoint of the course rather than at the point of departure. The course measured on the chart is known as the true course. This is the direction measured by reference to a meridian or true north. It is the direction of intended flight as measured in degrees clockwise from true north.

As shown in figure 14-5, the direction from A to B would be a true course of 065°, whereas the return trip (called the reciprocal) would be a true course of 245°.

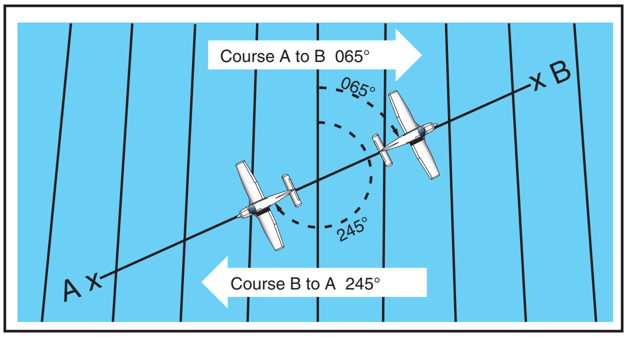

Figure 14-5. Courses are determined by reference to meridians on aeronautical charts.

The true heading is the direction in which the nose of the airplane points during a flight when measured in degrees clockwise from true north. Usually, it is necessary to head the airplane in a direction slightly different from the true course to offset the effect of wind. Consequently, numerical value of the true heading may not correspond with that of the true course. This will be discussed more fully in subsequent sections in this chapter. For the purpose of this discussion, assume a no-wind condition exists under which heading and course would coincide. Thus, for a true course of 065°, the true heading would be 065°. To use the compass accurately, however, corrections must be made for magnetic variation and compass deviation.

VARIATION

Variation is the angle between true north and magnetic north. It is expressed as east variation or west variation depending upon whether magnetic north (MN) is to the east or west of true north (TN).

The north magnetic pole is located close to 71° N. latitude, 96° W. longitude and is about 1,300 miles from the geographic or true north pole, as indicated in figure 14-6. If the Earth were uniformly magnetized, the compass needle would point toward the magnetic pole, in which case the variation between true north (as shown by the geographical meridians) and magnetic north (as shown by the magnetic meridians) could be measured at any intersection of the meridians.

Actually, the Earth is not uniformly magnetized. In the United States, the needle usually points in the general direction of the magnetic pole, but it may vary in certain geographical localities by many degrees. Consequently, the exact amount of variation at thousands of selected locations in the United States has been carefully determined. The amount and the direction of variation, which change slightly from time to time, are shown on most aeronautical charts as broken magenta lines, called isogonic lines, which connect points of equal magnetic

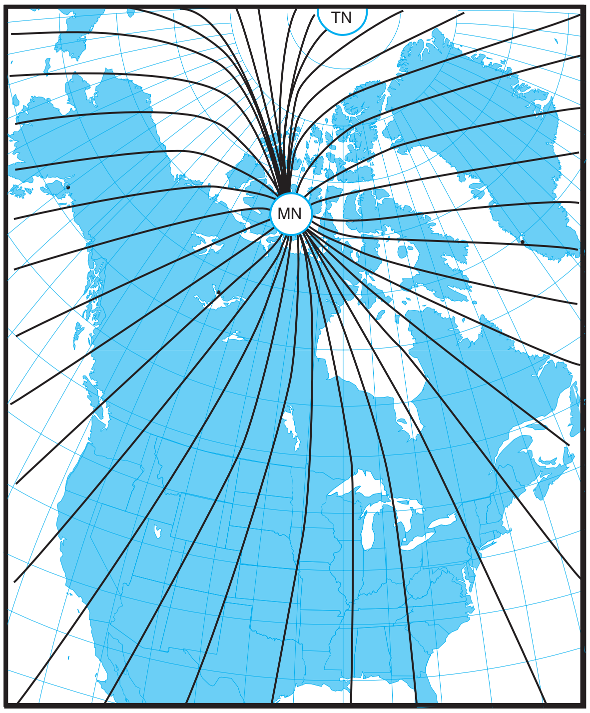

Figure 14-6. Isogonic chart. Magnetic meridians are in black; geographic meridians and parallels are in blue. Variation is the angle between a magnetic and geographic meridian.

variation. (The line connecting points at which there is no variation between true north and magnetic north is the agonic line.) An isogonic chart is shown in figure 14-6. Minor bends and turns in the isogonic and agonic lines are caused by unusual geological conditions affecting magnetic forces in these areas.

On the west coast of the United States, the compass needle points to the east of true north; on the east coast, the compass needle points to the west of true north. Zero degree variation exists on the agonic line, where magnetic north and true north coincide. This line runs roughly west of the Great Lakes, south through Wisconsin, Illinois, western Tennessee, and along the border of Mississippi and Alabama. [Compare figures 14-7 and 14-8.]

Because courses are measured in reference to geographical meridians which point toward true north, and these courses are maintained by reference to the compass which points along a magnetic meridian in the general direction of magnetic north, the true direction must be converted into magnetic direction for the purpose of flight. This conversion is made by adding or subtracting the variation which is indicated by the nearest isogonic line on the chart. The true heading, when corrected for variation, is known as magnetic heading.

If the variation is shown as "9°E," this means that magnetic north is 9° east of true north. If a true heading of 360° is to be flown, 9° must be subtracted from 360°, which results in a magnetic heading of 351°. To fly

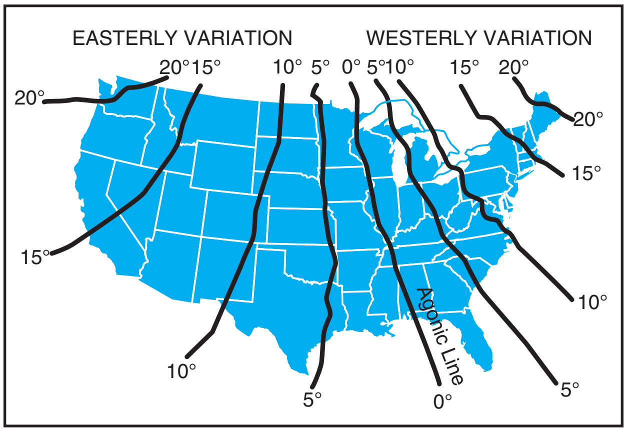

Figure 14-7. A typical isogonic chart. The black lines are isogonic lines which connect geographic points with identical magnetic variation.

east, a magnetic heading of 081° (090° – 9°) would be flown. To fly south, the magnetic heading would be 171° (180° – 9°). To fly west, it would be 261° (270° – 9°). To fly a true heading of 060°, a magnetic heading of 051° (060° – 9°) would be flown.

Remember, to convert true course or heading to magnetic course or heading, note the variation shown by the nearest isogonic line. If variation is west, add; if east, subtract. One method for remembering whether to add or subtract variation is the phrase "east is least (subtract) and west is best (add)."

DEVIATION

Determining the magnetic heading is an intermediate step necessary to obtain the correct compass heading for the flight. To determine compass heading, a correction for deviation must be made. Because of magnetic influences within the airplane such as electrical circuits, radio, lights, tools, engine, and magnetized metal parts, the compass needle is frequently deflected from its normal reading. This deflection is deviation. The deviation is different for each airplane, and it also may vary for different headings in the same airplane. For instance, if magnetism in the engine attracts the north end of the compass, there would be no effect when the plane is on a heading of magnetic north. On easterly or westerly headings, however, the compass indications would be in error, as shown in figure 14-9. Magnetic attraction can come from many other parts of the airplane; the assumption of attraction in the engine is merely used for the purpose of illustration.

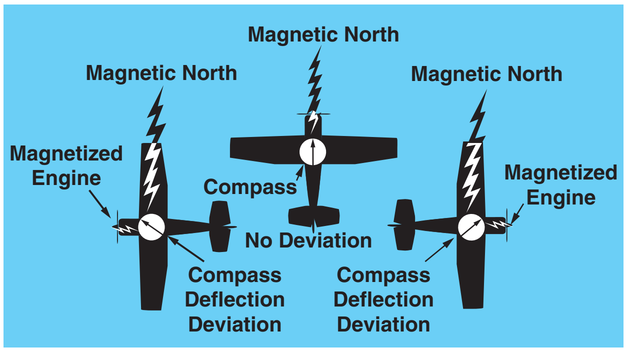

Figure 14-9. Magnetized portions of the airplane cause the compass to deviate from its normal indications.

Some adjustment of the compass, referred to as compensation, can be made to reduce this error, but the remaining correction must be applied by the pilot.

Proper compensation of the compass is best performed by a competent technician. Since the magnetic forces within the airplane change, because of landing shocks, vibration, mechanical work, or changes in equipment, the pilot should occasionally have the deviation of the compass checked. The procedure used to check the deviation (called "swinging the compass") is briefly outlined.

The airplane is placed on a magnetic compass rose, the engine started, and electrical devices normally used (such as radio) are turned on. Tailwheel-type airplanes should be jacked up into flying position. The airplane is aligned with magnetic north indicated on the compass

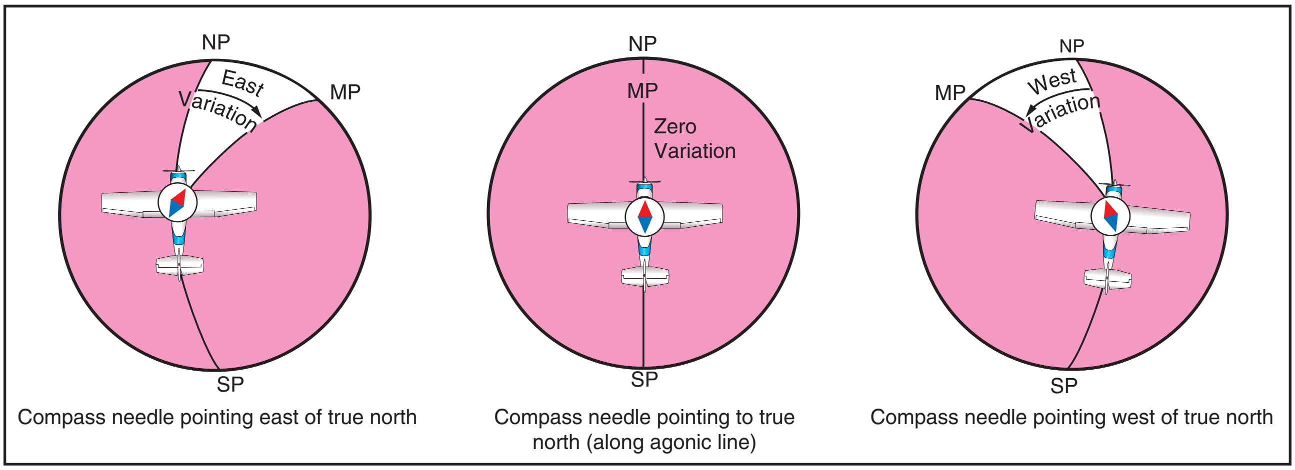

Figure 14-8. Effect of variation on the compass.

rose and the reading shown on the compass is recorded on a deviation card. The airplane is then aligned at 30° intervals and each reading is recorded. If the airplane is to be flown at night, the lights are turned on and any significant changes in the readings are noted. If so, additional entries are made for use at night.

The accuracy of the compass can also be checked by comparing the compass reading with the known runway headings.

A deviation card, similar to figure 14-10, is mounted near the compass, showing the addition or subtraction required to correct for deviation on various headings, usually at intervals of 30°. For intermediate readings, the pilot should be able to interpolate mentally with sufficient accuracy. For example, if the pilot needed the correction for 195° and noted the correction for 180° to be 0° and for 210° to be +2°, it could be assumed that the correction for 195° would be +1°. The magnetic heading, when corrected for deviation, is known as compass heading.

FOR (MAGNETIC)..........	N	30	60	E	120	150
STEER (COMPASS).......	0	28	57	86	117	148
FOR (MAGNETIC)..........	S	210	240	W	300	330
STEER (COMPASS).......	180	212	243	274	303	332

Figure 14-10. Compass deviation card.

The following method is used by many pilots to determine compass heading: After the true course (TC) is measured, and wind correction applied resulting in a true heading (TH), the sequence TH ± variation (V) = MH ± deviation (D) = compass heading (CH) is followed to arrive at compass heading. [Figure 14-11]

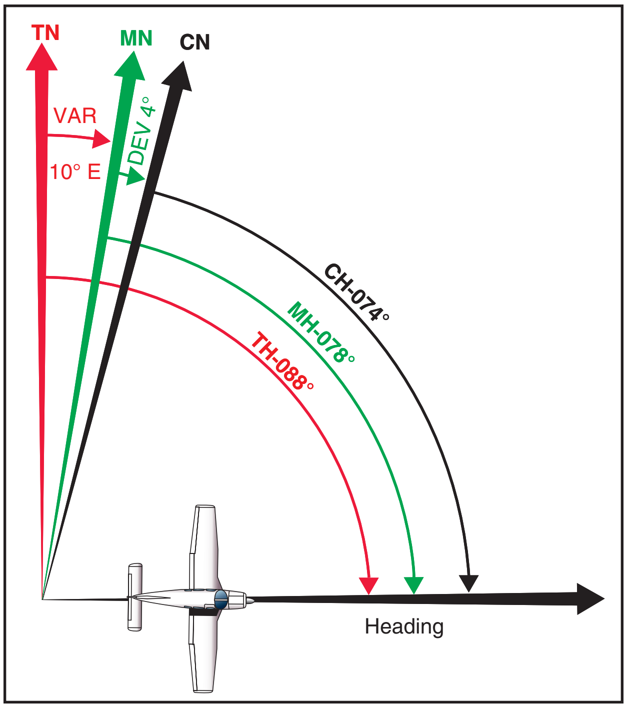

Figure 14-11. Relationship between true, magnetic, and compass headings for a particular instance.

EFFECT OF WIND

The preceding discussion explained how to measure a true course on the aeronautical chart and how to make corrections for variation and deviation, but one important factor has not been considered—wind. As discussed in the study of the atmosphere, wind is a mass of air moving over the surface of the Earth in a definite direction. When the wind is blowing from the north at 25 knots, it simply means that air is moving southward over the Earth's surface at the rate of 25 nautical miles (NM) in 1 hour.

Under these conditions, any inert object free from contact with the Earth will be carried 25 NM southward in 1 hour. This effect becomes apparent when such things as clouds, dust, and toy balloons are observed being blown along by the wind. Obviously, an airplane flying within the moving mass of air will be similarly affected. Even though the airplane does not float freely with the wind, it moves through the air at the same time the air is moving over the ground, thus is affected by wind. Consequently, at the end of 1 hour of flight, the airplane will be in a position which results from a combination of these two motions:

- the movement of the air mass in reference to the ground, and
- the forward movement of the airplane through the air mass.

Actually, these two motions are independent. So far as the airplane's flight through the air is concerned, it makes no difference whether the mass of air through which the airplane is flying is moving or is stationary. A pilot flying in a 70-knot gale would be totally unaware of any wind (except for possible turbulence) unless the ground were observed. In reference to the ground, however, the airplane would appear to fly faster with a tailwind or slower with a headwind, or to drift right or left with a crosswind.

As shown in figure 14-12, an airplane flying eastward at an airspeed of 120 knots in still air, will have a groundspeed exactly the same—120 knots. If the mass of air is moving eastward at 20 knots, the airspeed of the airplane will not be affected, but the progress of the airplane over the ground will be 120 plus 20, or a groundspeed of 140 knots. On the other hand, if the mass of air is moving westward at 20 knots, the airspeed of the airplane still remains the same, but groundspeed becomes 120 minus 20 or 100 knots.