



February 2008 Departments

The Weather Never Sleeps

Dangerous lies

By Jack Williams

Keeping your altimeter honest

Aviation, more than many activities, is built on trust. Almost all of the time this trust is well placed. One instrument, however, is most likely to be the exception. Unless you understand it and keep it in line, an altimeter can tell you some dangerous lies.

Fortunately, understanding an aircraft altimeter isn't rocket science. Once you understand it, and make keeping it in line a part of your flying routine, you won't have to worry about extracting the truth from an altimeter.

A good place to begin is to learn exactly what the altimeter is supposed to be telling you. First, you need to understand some definitions.

Altimetry definitions

- **Above ground level (agl):** The term commonly used in aviation for absolute altitude.
- **Absolute altitude:** The height of an aircraft above the surface directly below.
- **Elevation:** The height of the top of a physical feature, such as a mountain, building, or tower above mean sea level.
- **Height:** The distance from the top of a structure to the Earth's surface at its base.
- **Indicated altitude:** The height above mean sea level that an altimeter reads.
- **Mean sea level:** The average level of the top of the world's oceans without taking into account tides, storms, and other effects that raise or lower sea level.
- **Pressure altitude:** The reading of an altimeter set to 29.92 inches of mercury. This reading is the height above the standard datum plane. In the United States, aircraft above 18,000 feet set their altimeters at 29.92 to fly at assigned pressure altitudes.
- **Pressure surface:** A surface, or plane, in the atmosphere where the atmospheric pressure is the same value. The height of a pressure surface at any location depends on patterns of atmospheric pressure and temperature.
- **Standard datum plane:** The pressure surface where the pressure is 29.92 inches of mercury, or would be if the pressure could be measured. If the sea-level pressure is less than 29.92 inches of mercury, the standard datum plane is below the surface.
- **True altitude:** An aircraft's height above mean sea level.

As a pilot your main concern with altitude is staying well above any mountain tops, high towers, or buildings near your route of flight. To do this, you'll study the aeronautical chart for the area and select a true altitude above mean sea level that keeps you away from mountains, towers, and other obstructions.

The altimeter on your panel, which will help you maintain a desired true altitude, is called a *pressure altimeter* because it detects the pressure of the air around the airplane. Instead of reading in inches of mercury or millibars (the ordinary units of air pressure) an altimeter reads feet above sea level. The key to ensuring that your altimeter is telling the truth is to keep it adjusted to the altimeter setting of the area over which you're flying. Every time you adjust your altimeter you are honoring the inventor of the *sensitive altimeter*. You read the setting in the *Kollsman window*, named for Paul Kollsman, the German-born inventor who had just started his own company in the United States in 1928 when Army Air Corps pilot Jimmy Doolittle made the first "blind" (today we say "instrument") flight using one of Kollsman's altimeters.

A pressure altimeter takes advantage of the fact that the air's pressure decreases as we go higher. If you're climbing a mountain you could use a mercury barometer to measure your altitude. But, a mercury barometer has to be at least 32 or so inches long, and you'd have to worry about turbulence sloshing the mercury out of the cistern that holds the mercury at the bottom of the tube. Instead, an altimeter uses an *aneroid*--a mechanical device that senses air pressures and uses gears and levers to move the pointers on the instrument's face to indicate the altitude.

Since the air pressure decreases at a generally steady rate with altitude, a barometer can be used to measure altitude. Pilots are often told that pressure decreases by one inch of mercury for each 1,000 feet of altitude gained. That's not quite true; it's a rule of thumb, but it's close enough for the first 10,000 or so feet above sea level. We'll use it in our examples.

Imagine that your airplane is based at an airport at sea level. On a nice, average day, the air pressure at the airport is 29.92 inches of mercury, and your altimeter is reading 0 feet on the ground. On the ground at sea level your true altitude is zero. When you climb to 1,000 feet the altimeter senses a

pressure of 28.92 (using the rule of thumb) and reads 1,000 feet.

Now, imagine going out to your airplane at the sea-level airport on a stormy day when the airport's barometer is reading 29.42 inches. You see the altimeter is reading 500 feet because the altimeter is sensing the air pressure found at 500 feet (29.92 minus 0.50 inches). If you did go flying that day without adjusting the altimeter, it would continuously read 500 feet high.

After the storm passes, you could see that the altimeter needle is below the zero mark; the air pressure is now 30.02 inches and the altimeter is trying to read minus 100 feet since an altimeter reads higher pressure as lower altitude. To correct this, you turn the altimeter adjusting knob until it reads 0 feet--your sea-level airport's elevation. You see that the pointer in the Kollsman window is at 30.02.

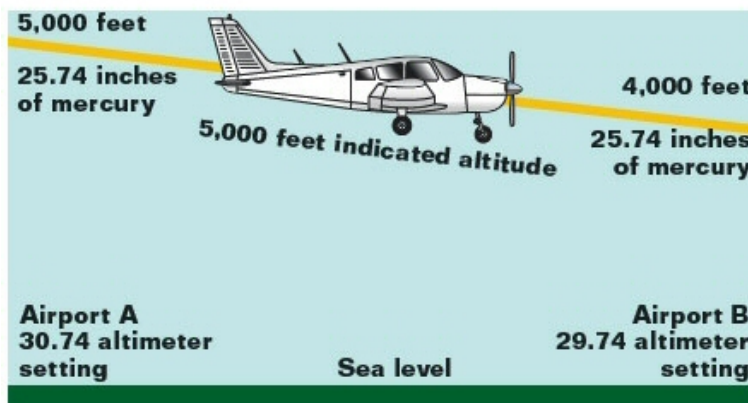
Obviously, an altimeter has to be adjusted to take account of weather changes that increase or decrease the air's pressure. Turning the knob to bring the reading to the airport's elevation before you take off works fine if you're going to spend an hour flying around the pattern, but could lead you into trouble if you fly to an airport where the air pressure is higher or lower, especially lower.

This is why weather stations calculate and broadcast the altimeter setting. This figure is what the air pressure would be at sea level at the location, if it could be measured at sea level. It's calculated by measuring the station pressure, which is the actual barometer reading, and using the altimeter formula solved for the reference pressure, which is the sea level pressure.

When you're flying between airports the federal aviation regulations require you to "fly by reference to an altimeter" that is set to the current, reported altimeter setting of a station along your route and within 100 nautical miles of your location.

Figure 1 shows the consequences of flying to another airport, where the pressure is lower, without dialing in the altimeter setting of the destination before you prepare to land. In the figure you take off from Airport A on the left, where the altimeter setting is 30.74 inches of mercury. You want to cruise at 5,000 feet, which means you level off when your altimeter senses a pressure of 25.74 inches of mercury.

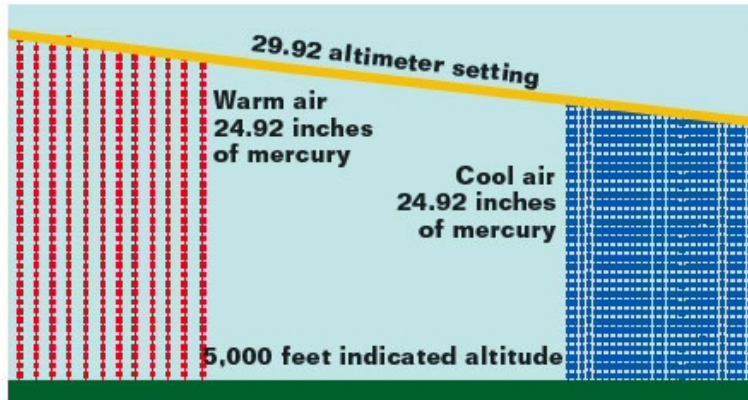
Figure 1



By setting your altimeter at 30.74 before taking off, you--in effect--told the altimeter that a pressure of 25.74 equals 5,000 feet. Since you are flying toward an area of lower atmospheric pressure, the altitude where the pressure is 25.74 inches of mercury slopes down toward the right. If you don't adjust your altimeter to Airport B's setting of 29.74 inches, you'll be 1,000 feet lower than your altimeter reads.

Obviously, being lower than you think you are can be dangerous. Thus, the aviation saying: "High to low, look out below." Flying into an area of higher atmospheric pressure means that if you don't change your altimeter to the correct setting, your true altitude will be higher than the indicated altitude. You could be closer to the top of a television antenna than you think you are.

Figure 2 shows why "high to low, look out below" also applies to flying from a higher to a lower temperature can be dangerous. When the air is cold its molecules are closer together; a column of air shrinks just as most things do when they are chilled. This means that the altitudes of the various pressures aloft will be lower in the cold air than in the warm air, even though the pressure at the surface is the same. Surface pressure depends on how much air is above a point. The same amount of air is above all of the points in Figure 2, but the column of air is higher in the warm air on the left; the air has expanded.

Figure 2

We've been assuming that with changes in air pressure at the surface the pressure decreases at the same rate as you climb. But, in the atmosphere you will find areas of high and low air pressure aloft as well as at the surface. This means that as you climb the relation between altitude and air pressure doesn't change at the rate predicted by the altimeter formula.

This is why in the United States pilots change the altimeter setting to 29.92 inches of mercury when they climb above 18,000 feet, and change back to the setting of the nearest altimeter-setting reporting station as they descend below 18,000 feet. The altimeter reading when it's set at 29.92 is called the *pressure altitude*. This figure is used because 29.92 inches of mercury is the sea-level pressure in the standard atmosphere, which you can think of as the global average atmosphere.

As Figure 1 shows, all high-flying aircraft in a particular area will be flying along surfaces with a particular atmospheric pressure, not at true altitudes. This ensures that they will stay the same distance above and below each other no matter how the pressure changes in relation to true altitude.

Pilots need to stay alert and be aware of distractions when changing altimeter settings. Otherwise, their altimeter could lie to them, leading to trouble.

Jack Williams is coordinator of public outreach for the American Meteorological Society. An instrument-rated private pilot, he is the author of The USA Today Weather Book and The Complete Idiot's Guide to the Arctic and Antarctic, and co-author with Bob Sheets of Hurricane Watch: Forecasting the Deadliest Storms on Earth.

[Back](#)

[Flight Training Archives Contents](#)