

# *Altimetry for Mountaineers and Hikers*

## *A brief summary*

- Understanding Altimetry
  - How changes in weather can affect your pressure altimeter.
  - How elevation effects your pressure altimeter
  - How air temperature effects air density and your climbing performance

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# Altimetry

- Why is Altimetry Important? You need to understand how to use an altimeter, but also what factors can effect its accuracy.
  - Good mountaineering /hiking practice usually requires the use of an altimeter. Topography and Contour maps are very limited without knowing what your “correct” elevation is. A map & compass provides you with information about where you are horizontally. If you know exactly where you are on a map then you can determine your elevation. But an altimeter can “directly” provide you with elevation. Since we move about in a 3-dimentional world, then knowing how to use an altimeter, and what its limitations are, is just as important as knowing how to use a compass.
- With an Altimeter you can
  - *Perform Bearing-Elevation Intersects*: The point at which a compass bearing intersects an elevation contour line. Use your compass and altimeter collectively to locate your position.
  - *Perform Feature-Elevation Intersects*: The point at which a known feature, such as a creek, road, or ridge intersects your known elevation.
  - Use your altimeter/barometer to predict weather changes. High pressure systems are generally associated with stable, dry weather. Low pressure systems are the predictors of possible rain, snow, thunder activity, and cooler temperatures.
  - Use your altimeter to estimate elevation gain per hour, and adjust your pace accordingly. You can re-estimate ETA based on ascent/descent rate alone.
  - Can you think of other uses for an altimeter?

# Altimetry

- Terms, Definitions, and Concepts
  - Actual Altitude
    - Your actual altitude is your physical altitude above sea-level, usually measured in feet or meters. For example, when you are standing on the summit Long's Peak you are 14,259 ft above sea level. This altitude is your Actual Altitude because it is directly measured above mean sea level (MSL).
  - Air density (and thus air pressure) decreases with an increase in Altitude. Why?
  - Pressure Altitude
    - On a Standard Day, pressure at sea level is 29.92 inches of Hg. This is because the weight of the atmosphere at sea level will cause mercury to rise 29.92 inches in a monometer tube. A drop of 1 inch of Hg roughly corresponds to an elevation increase of 1,000 feet, because pressure decreases as altitude increases. Pressure altitude is defined as your altitude above the 29.92 in-Hg datum curve. The 29.92 in-Hg datum curve will be above actual sea level in a high pressure system. It will be lower than actual sea level in a low pressure system.
  - Pressure Altimeters
    - Measures only Pressure Altitude. Pressure altimeters measure the existing atmospheric pressure at your altitude, compare it to a reference pressure (usually sea level pressure), then converts it into feet of elevation. **Remember -- A pressure altimeter doesn't have a clue as to what your Actual Altitude is, anymore than a magnetic compass has a clue as to where True North is.**
  - GPS Altimetry
    - Altimeters based on GPS telemetry data are not affected by changes in atmospheric pressure. They operate effectively in most weather environments, but are limited by satellite coverage, as well as by the number of satellites that your receiver can acquire at any given time. A minimum of 4 viewable satellites are necessary in order to provide you with a 3-D position fix. GPS accuracy is mainly determined by the number and position of satellites that you are able to track.

# Pressure System in a Stationary Front (Standard Day)

Altimeter reads 6500 ft.



6,500 ft Summit

23.42 inches Hg

$Press\ Alt = (29.92 - 23.42) \times 1000 = 6500\ ft.$   
Altimeter reads 6,500 ft. (Accurate Reading)

Mountain Summit

24.92 inches Hg

**Altimeter Reads Correct Altitude**

25.92 inches Hg

Actual Altitude = 6,500 ft  
Pressure Altitude = 6,500 ft

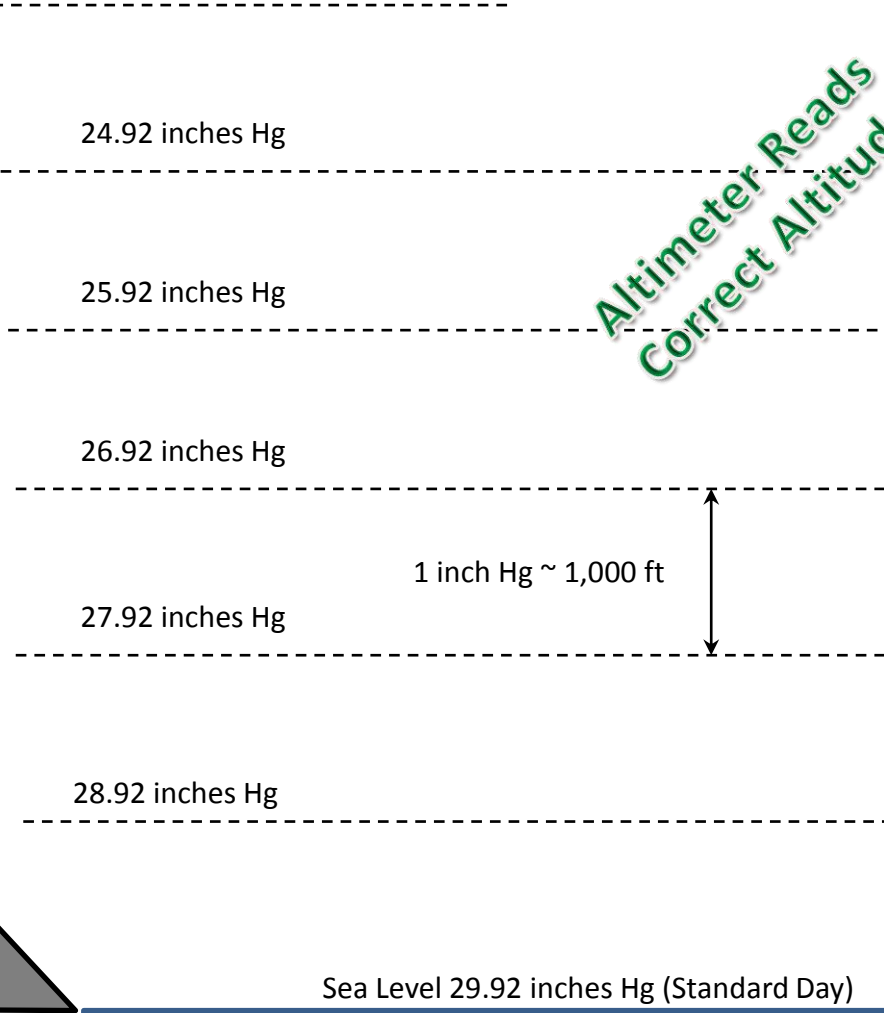
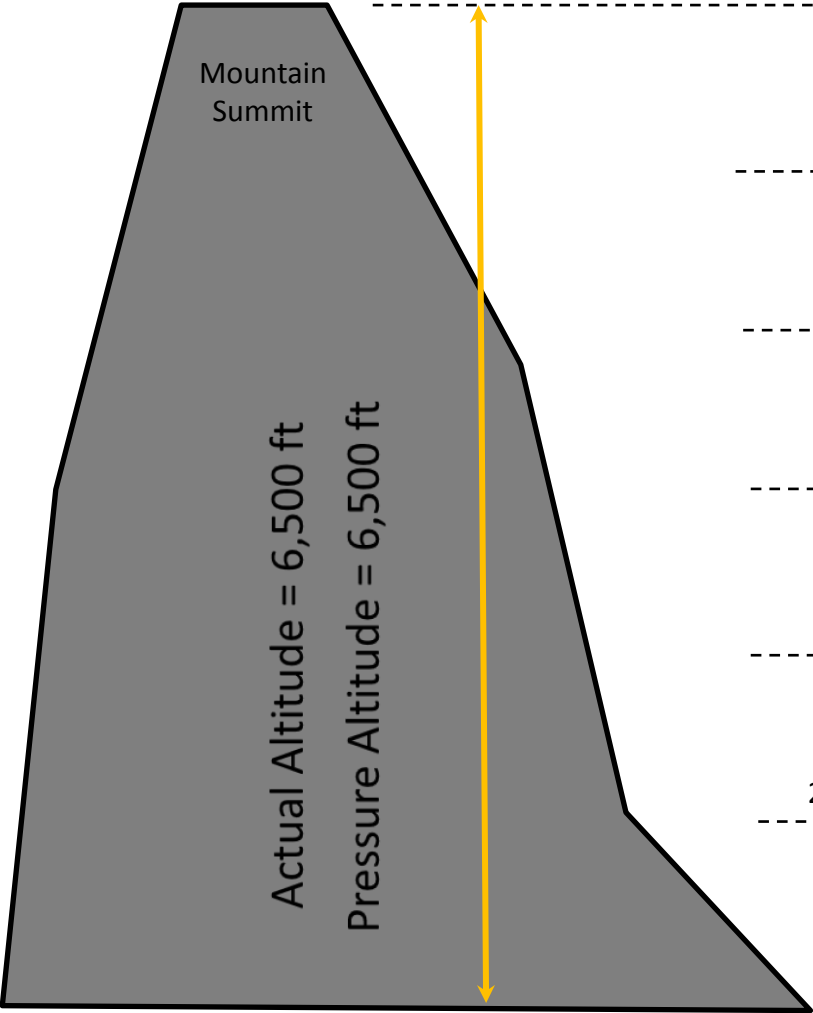
26.92 inches Hg

1 inch Hg ~ 1,000 ft

27.92 inches Hg

28.92 inches Hg

Sea Level 29.92 inches Hg (Standard Day)



# High Pressure System Replaces a Standard Day

Altimeter reads 5340 ft.



6,500 ft Summit

24.58 inches Hg

$$\text{Press Alt} = (29.92 - 24.58) \times 1000 = 5340.$$

Altimeter reads 5,340 ft. (Reads 1160 feet too low)

25.92 inches Hg

26.92 inches Hg

27.92 inches Hg

28.92 inches Hg

29.92 inches Hg

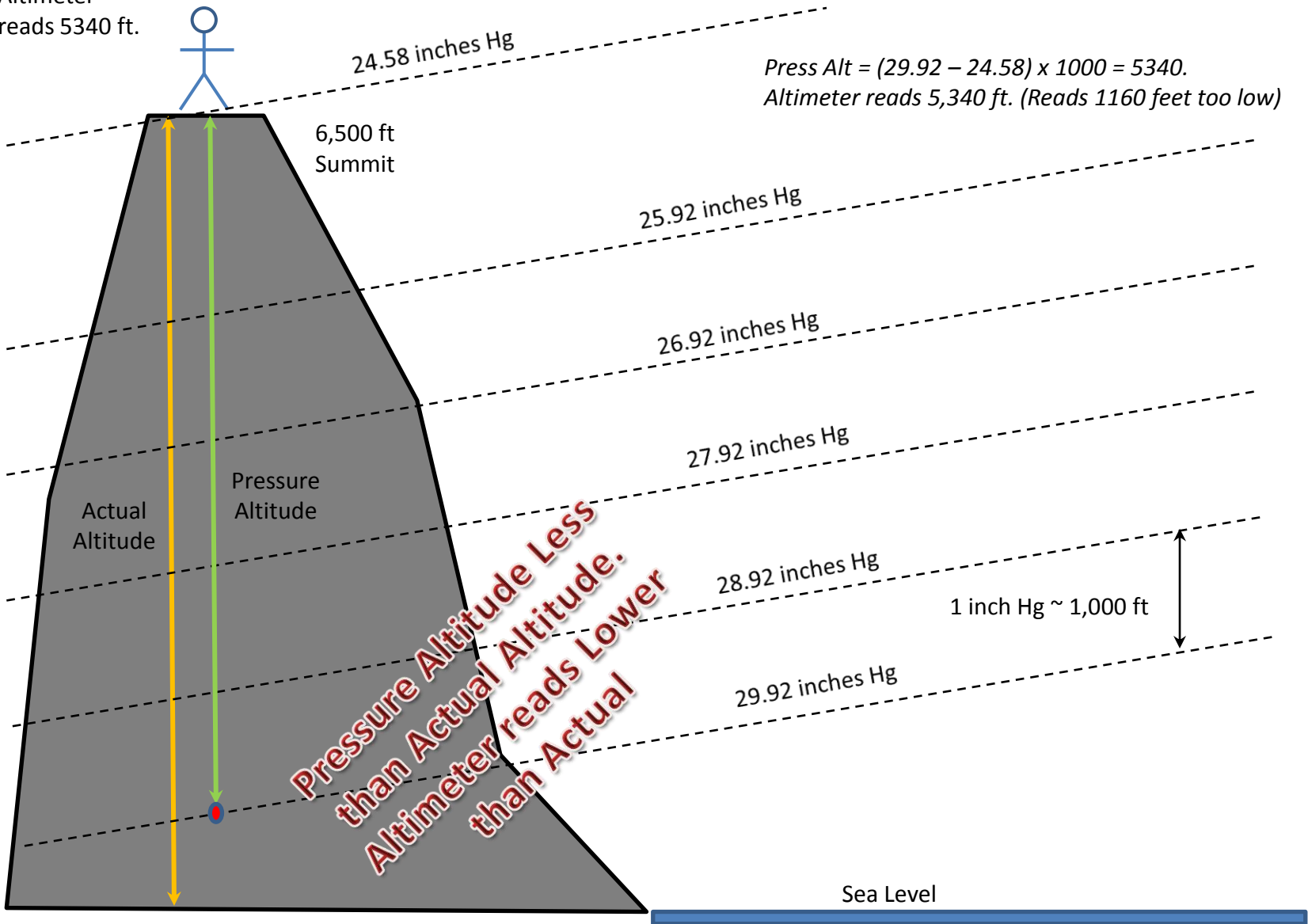
Actual Altitude

Pressure Altitude

**Pressure Altitude Less than Actual Altitude.  
Altimeter reads Lower than Actual**

1 inch Hg ~ 1,000 ft

Sea Level



# Low Pressure System Replaces a Standard Day

Altimeter reads 7170 ft.



22.75 inches Hg

6,500 ft Summit

$Press\ Alt = (29.92 - 22.75) \times 1000 = 7170.$   
Altimeter reads 7,170 ft. ( Reads 670 feet too high)

25.92 inches Hg

1 inch Hg ~ 1,000 ft

26.92 inches Hg

Pressure Altitude

Actual Altitude

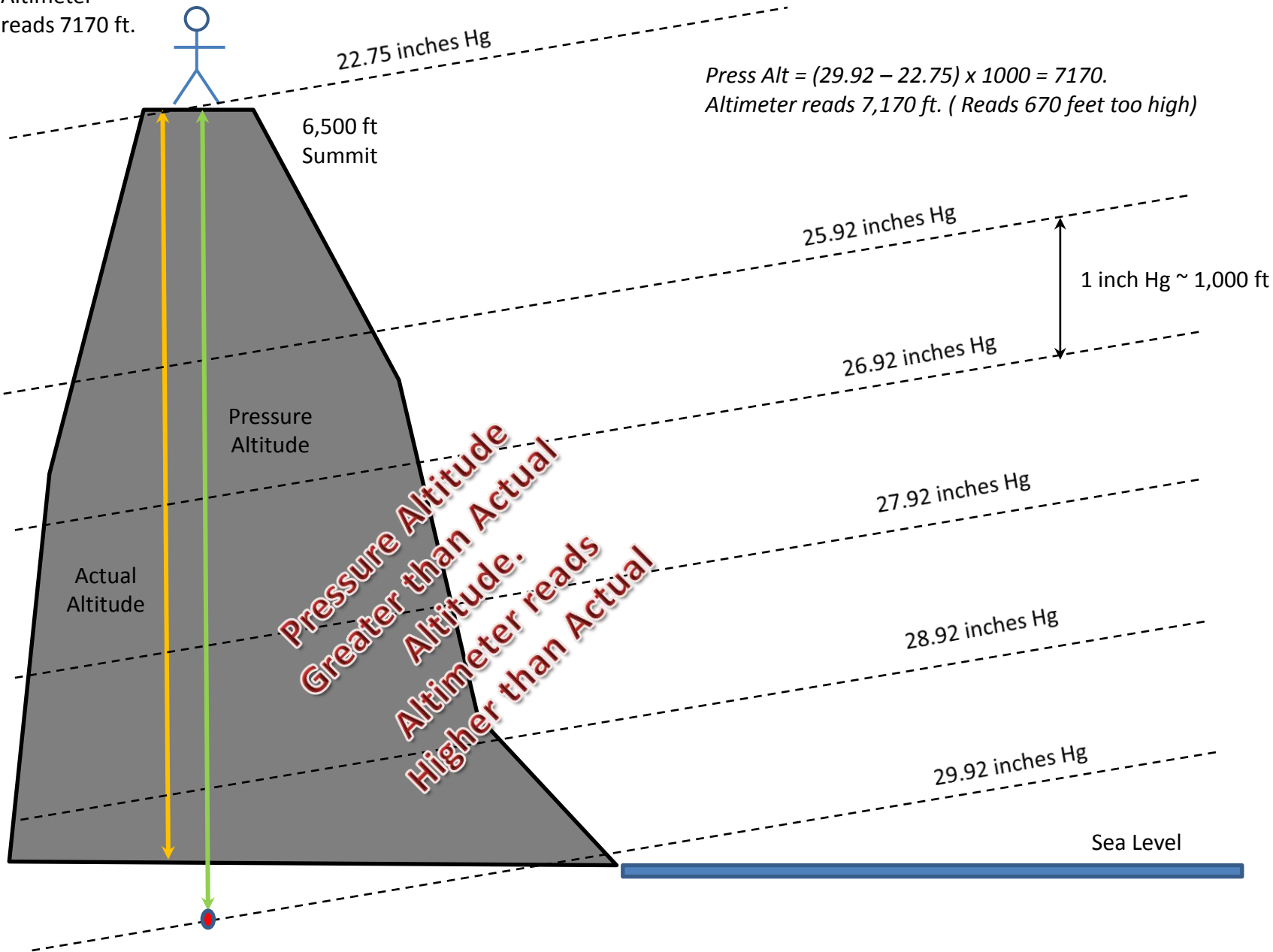
**Pressure Altitude Greater than Actual Altitude.  
Altimeter reads Higher than Actual**

27.92 inches Hg

28.92 inches Hg

29.92 inches Hg

Sea Level



# The Least You Should Know

- Most altimeter errors occur when you have set your altimeter to a known elevation when you start hiking, and then you do not recalibrate your altimeter when the atmospheric pressure changes throughout the day.
- **Things to Remember**
  - If you set your altimeter to a bench-mark altitude when you begin your hike and during your hike the barometric pressure
    - **Increases**, then your altimeter will indicate a lower than actual reading.
    - **Decreases**, then your altimeter will indicate a higher than actual reading.
  - A Rule-of-Thumb saying that pilots often use to remember this is “From high to low, look out below.” In other words, while going from a high pressure system to a low pressure system, your altimeter will read higher than your actual altitude. That is – you will think that you are higher than you actually are. So look out below. This applies to mountaineers as well as to aviators.
  - It’s always a good practice to reset your altimeter to a known elevation (usually from a known elevation fix on your map) every couple of hours. Alternatively, if you carry a GPS, you can reset your pressure altimeter to correlate with the elevation shown on your GPS. Be sure that you have adequate satellite coverage if you do this. Greater satellite coverage is necessary to determine your elevation than it is to determine your horizontal location.
  - Pressure altimeters use barometric pressure to covert pressure data into elevation. If the barometric pressure changes, then your altimeter will also change, even if you remain stationary and your actual elevation does not change. Remember, pressure altimeters don’t know the difference between an ascending climber or the arrival of a low pressure system. It will behave identically in both situations. It only knows that the atmospheric pressure is changing.

# Additional Cool Stuff

- How to determine your elevation without any terrain features, benchmark elevations, or a GPS receiver. *An alternate method.*
  - Assume you have no references to an altitude. You're lost. Now what? Most pressure altimeters today allow the user to manually enter existing sea level barometric pressure. When you enter the local barometric sea-level pressure the altimeter compares that value to the existing outside pressure at your location, then converts it to a corrected altitude. If hiking or climbing within 150 miles of Denver International Airport, and assuming you have cell service, you can get sea level pressure by calling (303) 342-0838 and listening to the automated ATIS (Automated Terminal Information Service) recording. The "Altimeter Setting" is the value that you will enter into your altimeter. Once you do this, your altimeter should read your correct, actual altitude above sea level. The altimeter setting provided to you by ATIS is already corrected to sea level. For example, if ATIS reports the altimeter setting at 30.15, then it means that the barometric pressure at seal level at your location is 30.15 in-Hg. Be sure that your altimeter has the capability to have the altimeter setting entered in this manner. Most Suunto and Casio altimeters have this capability. Before purchasing an altimeter, you may want to check to be sure that it has this capability.
  - Since barometric pressure changes throughout the day, so does the local altimeter setting. ATIS recordings are used primarily by pilots, but anyone can make use of them, including mountaineers. Recordings are updated every hour. Barometric pressures do not typically change appreciably within 150 miles of a reporting station. So within that range you can use DIA's current ATIS to obtain a reliable altimeter setting, and thus your elevation. All major airports in the U.S. provide this service, and have phone numbers where you can listen to their ATIS. If the pressure **does** change appreciably within 150 miles of your location, then you shouldn't be outdoors. You should be avoiding intense thunderstorms or in a tornado shelter.



# Air Temperature Considerations on Performance

- Both air temperature and elevation have an effect on your climbing performance, and your ability to think and exercise good judgment. Temperature affects air density. In general, the warmer the air is, the less dense it is. As the density of the air decreases, you take in less oxygen with each breath. Every time you summit a high peak your performance will be diminished because the amount of available oxygen is diminished.
- Performance Altitude determines how well you will perform, think, and exercise good judgment at a given location. Experienced high peak climbers know their own bodies and their limitations. They know how their bodies and their brains will perform while hiking and climbing at high elevations. What might not be so obvious is the effect that higher-than-standard air temperatures can have on Performance Altitude.
- Performance Altitude is the altitude that your body registers, regardless of your actual altitude. For those of you who are pilots, Performance Altitude is closely related to Density Altitude, which is Pressure Altitude corrected for non-standard temperature. Planes, trains, and automobiles are like people. They are air-breathing machines. Their performance also decreases with an increase in altitude (unless they are turbocharged). But there is an altitude above which an airplane won't go. Unless you are turbocharged, the same holds true for you. Recognize the signs of AMS (Acute Mountain Sickness) in yourself and in others.

# High Peak Climb Scenario

- Here's a scenario
  - You are preparing to go climb Longs Peak. You climbed it in early March and experienced only slight symptoms of AMS. You made it to the summit easily enough though, where the temperature was 5°F. But now it's August, and it's a sizzling 93°F in Boulder. It's warm on the mountain too. As you ascend through the Keyhole (13,100 ft) you begin to feel winded and queasy. Each step becomes an effort. This time around it takes all you've got to reach the summit (14,259 ft). At the summit you rest, rehydrate, and look at your thermometer. It indicates that the temperature at the summit is 59°F, warm for the summit. You are surprised at the effort required to get to the top. "It wasn't this tough back in March", you say to yourself. "Did I get out of shape"? Well, maybe. But more than likely it is the effect of higher-than-standard temperature on your performance.
  - Eating your Wheaties that morning probably won't help you much. Prolonged aerobic training at high altitude may help you. However, how well you perform at altitude is determined by many factors. Still, much of it is up to you. All the great climbing equipment in the world won't help you if you are not fit to climb. Train hard to climb hard. Stay in Mountaineering Shape. Colorado peaks are high & dry. That means that they can experience wide fluctuations in temperature between summer and winter, and even between night and day. Understand how variations in temperature can affect air density, and thus your performance.

# Performance Elevation

- The following table illustrates how temperature can affect air density, and thus the amount of available oxygen necessary to support your muscles and organs. Warmer-than-Standard temperatures can affect performance more than you might think.
- If you climb Longs Peak on a cold or average day, then your Performance Altitude is approximately the same as your Actual Altitude.
- If you climb Longs Peak on a really hot day, then that is no different than climbing a 17,000+ foot peak on a Standard Day. Your body will perform as if it is at nearly 18,000 feet above sea level. When the outside air temperature is 59°F on the summit of Longs Peak, roughly 58% of sea-level oxygen is available to you. Simply stated, 42% of the earth's atmosphere is below you under these conditions.

| Standard Day (29.92 in-Hg) |        |                  |                      |                            |                             |
|----------------------------|--------|------------------|----------------------|----------------------------|-----------------------------|
| Location                   | Season | Actual Elevation | Outside Air Temp (F) | Performance Elevation (ft) | Percent of Sea Level Oxygen |
| Downtown Denver            | Winter | 5,280            | 25                   | 4,298                      | 88.0%                       |
| Downtown Denver            | Summer | 5,280            | 90                   | 8,413                      | 77.6%                       |
| Difference                 |        | 0                | 65                   | <b>4,115</b>               |                             |
| The Keyhole                | Winter | 13,100           | 12                   | 13,127                     | 66.9%                       |
| The Keyhole                | Summer | 13,100           | 67                   | 16,517                     | 59.9%                       |
| Difference                 |        | 0                | 55                   | <b>3,390</b>               |                             |
| Longs Peak Summit          | Winter | 14,259           | 5                    | 14,097                     | 64.8%                       |
| Longs Peak Summit          | Summer | 14,259           | 59                   | 17,452                     | 58.1%                       |
| Difference                 |        | 0                | 54                   | <b>3,355</b>               |                             |

# Summary

- *Refer back to the Table*

- *When you climbed through the Keyhole in March, your body registered a Performance Altitude of 13,127 feet, only 27 feet higher than actual. In August, your body now registers a Performance Altitude of over 16,500 feet at the Keyhole. You've just climbed a 16'er without even realizing it – and you're not even at the summit yet. No wonder you were winded and queasy at the Keyhole.*
- *In March, your body registered a Performance Altitude of 14,097 feet at the summit of Longs Peak. The colder-than-standard air temperature made it “feel” like you were a couple hundred feet lower than actual. In August, as far as your oxygen intake is concerned, you just made a summit of a 17,452-foot peak. And you thought that you had to leave Colorado to get that experience. Can you climb an 18'er without feeling the effects of AMS? Something to consider before you embark on a high peak climb on that hot July or August weekend in Colorado.*

- *Key Points to Remember*

- *Understand how High and Low pressure systems can affect your altimeter.*
- *Know how to use your altimeter to help locate your position. Understand what errors can affect your altimeter. A pressure altimeter is just a barometer that computes altitude based on static pressure.*
- *Understand how higher-than-standard temperatures, coupled with high elevations, can affect your performance and your ability to exercise good judgment.*
- *Train hard. Train for your climbs. Stay in shape. Mountaineering is fun and rewarding. But it is also challenging. It is a serious business. Never under-estimate the mountain. The mountain does not care about you or your safety. If you exercise poor judgment, the mountain will always win.*
- *Know how your body reacts to the thin air at higher elevations. Know your performance limitations. The safety of everyone in your climbing party may depend on your knowledge of yourself.*