Appendices

Appendix One: Answers to quiz questions

Introduction:

1. Rising elevation on a stationary altimeter indicates: (**b**) decreasing pressure. This information can be important because *it may* indicate the approach of a low pressure system (i.e.-storm).

2. True/False: Air within a low pressure weather system generally moves toward the center of the low ans upward? **True**- see Chapter 3.

3. True/False: As a general rule of thumb: wind speeds decrease with height in the lower atmosphere? **False**- winds typically increase with height in the troposphere.

4. What is the windiest season in the Presidential Range of New Hampshire? (**c**) Winter. You do not have to know anything about this region to hazard a good guess-wind speeds are almost always highest during the winter months in any location, because of the temperature contrasts.

5. Cloud-to-ground lightning has the highest frequency of occurrence between the hours of: (**b**) 3-7pm. The actual peak time various to some degree from one region to the next, however the best answer is b.

6. True/False: Wave clouds and a mountain cloud cap indicated high winds near the summit of a mountain? **True**- you will find that more often than not, winds are moderate to high near the summit of a peak that has a cloud cap or is producing wave clouds.

7. True/False: Due to mixing of air in the atmosphere, a climber at 5000 m (16,400 ft) in the Alaska Range experiences roughly the same air temperature as a climber at the same elevation in the Himalaya? **False**- the temperature on each mountain of course depends on a number of factors, however, statistically (or climatologically), the climber in Alaska will be colder than his/her counterpart at the same elevation in the Himalaya.

8. Large thunderstorms typically develop over what time period: (**d**) 1-2 hours- you may find this hard to believe because you have observed large thunderstorm cloud systems live a lot longer than several hours. However, most of those thunderstorm systems (complexes) are made-up of many individual storms-hence they appear to have a much longer lifetime.

9. During the summer, air temperatures _______ as a major low pressure system approaches: (**b**) Cool down- This is true because cool air surrounds the low pressure center.

10. True/False: Most 'ground blizzards' occur after new snow has fallen? **True**.
11. On a night with no clouds and little wind, pick the location that will have the coldest morning

temperature: (**c**) Floor of a valley- this is so because the radiational cooling of the valley causes the cool dense air to sink toward the bottom of the valley during the night.

12. True/False: Precipitation (rain or snow) always increases with increasing elevation? **False**- in mid-latitude mountain ranges the amount of snow or rain per storm, per month, per year typically increases from sea-level to some height, after which the amount decreases with further increase in elevation. The height of maximum precipitation depends on a number of factors: air temperature, proximity to large moisture source, size of the mountain range to name a few.

13. True/False: The primary climbing seasons in Ecuador are May-September and January? **True**- see section on Andes in Chapter 8 for explanation.

14. True/False: Climate statistics are not useful in expedition planning since the weather on any given day can be dramatically different then the long-term normals? **False**- If you answered this question with a 'true', you should be shot. Of course the weather can be different then the climatic normals, however, climate statistics give you some idea of what type of weather you can expect- rainy season verses dry season, temperature ranges, windy season verses light winds, etc.

15. True/False: Water in the atmosphere always freezes when the air temperature is at or below 0^{o} C (32^{o} F)? **False**- many people may have gotten this question wrong because we are taught in school that water more or less turns into a solid when it reaches its freezing point. This is correct as long as there are ice or freezing nuclei in the water. In the atmosphere, in order for liquid water to turn into a solid, it most do so on some type of foreign material (dirt, dust, aerosols). If there are not enough of these ice nuclei in a parcel of air, the water will continue to cool below 0^{o} C (32^{o} F) as a liquid. See Chapter 5 and Appendix 3.

16. A large cumulus cloud generates the following types of 'wind': (**d**) all of the above. Updrafts and downdrafts are best developed within the cloud tower, horizontal winds can form near the ground as downdrafts make contact with the earth's surface and are forced to 'spread out'. See Chapter 5.

17. True/False: Wind chill temperatures <u>increase</u> with <u>decreasing</u> wind speeds? **True**- note carefully how the question is worded. Wind chill temperatures decrease (get colder) as wind speeds increase, so as wind speeds decrease- the wind chill temperature increases (warms).

score - for introduction quiz.

# correct answers	Action required
15-17	Climb on!!
11-14	Good show! - you know what your doing.
8-10	Your on the right track - with a little work you will be a weather god in no time.
4-7	Your weather skills need improvement - read on!

0-3 Stay at home, lock the doors and read a book!

Chapter 2 quiz

1. Name the four types of fronts: **cold, warm, stationary, occluded**.

2. True/False: The Coriolis force only changes wind speed, not wind direction? **False**- it changes or deflects wind direction. To the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

3. Oxygen is the: 1st, 2nd, 3rd, 4th most abundant gas found in a sample of air. **Second**.

4. A rising altimeter signifies what? **A drop in pressure**- in cases when the rise (drop) is large, it may indicate a developing storm.

5. Air moves in a ________________ direction around an are of low pressure in the Northern Hemisphere. **Counterclockwise**. (*Anticlockwise* for our British and Commonwealth readers)

6. True/False: More oxygen is available to a climber on the summit of K2 than to a climber on the summit of Mt. McKinley? **False**- more oxygen is available to you on McKinley than on K2.

7. A cold air mass moves: a) over b) through c) under, a warm air mass. **c) under**.

8. A westerly wind is moving in what direction? **From west-to-east**.

Chapter 3 quiz

1. True/False: The sky appears blue because oxygen decreases with elevation? **False**- The sky's color is a result of sunlight scattering off of nitrogen molecules. The blue sky gets darker with increase in elevation because of a decrease in air density- essentially there is a reduction in the amount of scattering that occurs.

2. ____________ is the transfer of heat from a hot to a cold body. **Conduction**.

3. Clouds absorb and emit _______________ radiation. **Longwave**.

4. True/False: In the Northern Hemisphere, south facing slopes generally receive less shortwave radiation than north facing slopes? **False**- south facing slopes receive more SW radiation.

5. For a given air temperature, the wind chill temperature ____________ as the wind speed increases. **Decreases** (gets colder).

Chapter 4 quiz

1. Name the three jet streams? **Arctic, Polar, Sub-tropical**.

2. True/False: Glacier winds only occur at night? **False**.

3. Barrier jets form when the lower atmosphere is _________. **Stable**.

4. True/False: Downslope wind storms only form when the upstream wind is nearly parallel with the mountain range? **False**- the winds should be perpendicular to the mountains.

5. True/False: Valley winds develop faster than slope winds? **False**- slope winds generally develop faster than valley winds because there is less air to heat over the slopes than in a valley.

6. True/False: The stronger the bond between ice particles, the more difficult it is for the wind to transport it? **True**.

7. Slope winds take about ________ minutes to develop after sunlight 'heats' the air. **Roughly 30 minutes**.

8. True/False: Downslope windstorms are common in the western Rockies? **False**- they are common along the eastern slopes of the Rockies.

Chapter 5 quiz

1. True/False: A cloud consists of many tiny liquid droplets and/or ice crystals held in suspension? **True**.

2. True/False: A wave cloud is only made-up of water droplets? **False**- it can consists of water droplets or ice crystals or both. Since wave clouds occur at higher elevations, they will however tend to be ice crystals.

3. Cumulus clouds are often __________ than they are wider. **Taller**.

4. True/False: Lightning is really cool? **False**- It will burn ya!

5. Supercooled liquid water exists at a temperature ______________ freezing. **Below**.

6. Orographic precipitation is primarily controlled by __________ speed. **Wind speed**.

7. True/False: As pristine ice crystals fall through a cloud and merge with other crystals they form what are called ____________. **Aggregate snowflakes.**

8. True/False: Rainbows only form when the angle of the sun with respect to the water droplet

is 22^o ? **False**- rainbows form at many angles with respect to the sun. Sun halo's produced by ice crystals form at an angle (arc) of 22^o from the sun.

9. In general, cooler air temperatures result in ___________ amounts of snowfall. **Smaller**.

10. Cumulus clouds consist of updrafts and ___________. **Downdrafts**.

Chapter 6 quiz

1. True/False: Weather balloons are launched at the same time no matter the location? **True**- at 0Z and 12Z.

2. Name at least two NWP models: **Eta, NGM, NOGAPS, AVN/MRF, RUC**, etc.

3. True/False: Radar can be used for long-term weather forecasting? **False**- radars are used to monitor current conditions and aid forecasting for several hours into the future.

4. What is freezing rain? **Rain that falls as a liquid but subsequently freezes as it makes contact with the ground, trees, wires, etc.**

5. True/False: Climate data is of little value when you are planning a major overseas expedition? **False**.

6. True/False: Lightning is not a hazard in the Rockies? **False**- if you got this wrong you should be made to walk the plank!

7. True/False: The mid-latitude storm track is closely associated with the sub-tropical jet stream? **False**- its associated with the polar jet stream

8. What range of wavelengths (visible, infrared, microwave) are used in satellite imagery to view/track clouds at night? **Infrared**.

Appendix Two: Skis and Snowboards

Have you ever wondered how skis or a snowboard slides across the snow? This topic lies within the realm of snow physics, nevertheless it has a lot of commonality with boundary-layer meteorology, hence we offer it to our readers.

Let's start this discussion by relating two experiences that all skiers (boarders) have: 1) when at rest skis have the tendency to resist motion to a certain degree (i.e.-stick); 2) when the temperature of both snow and air is cold, skis have reduced glide, sometimes very little glide at all. The common theme in these two cases is friction. Physics teaches us that there are two kinds of friction: static (at rest) and dynamic (in motion). When you are at rest on level ground it takes a certain amount of energy to move the first meter, however, it takes less energy to move the second meter. This results from the fundamental fact that static friction is larger than dynamic friction. Friction is the resistance to motion between two material objects (similar to viscosity in fluids). In our example friction takes place between the bottom of the ski (p-tex) and the snow particles in the upper layers of the snowpack. If you think that friction is temperature dependent, you are absolutely correct, the colder the snow, the greater the friction between ski and snow. Nordic skiers know this all too well. Skate skiers have a difficult time producing glide when the snow and air temperatures drop much below -10° C (14° F). At these cold temperatures diagonal skiers may have better luck since the kick zone of the ski requires a considerable amount of friction anyway.

There is an additional consideration that must be factored into the physics of sliding: water. Due to frictional heating between the ski and snow, snow particles directly underneath the ski melt, providing a microscopic layer of water that lubricates the ski and reduces the dynamic friction. The "cool" thing about this process is that it occurs when both the bottom of the ski and the snow are below freezing. This is possible because the weight of the skier creates very high pressures on the snow particles, which lowers the melting temperature. Amback and Mayr (1981) have show by empirical testing that the thickness of the water film created by frictional heating of a ski ranges between 5 and 20 microns (one micron equals 10^{-6} m or 0.001 mm or 0.00004 in), which is too small to be visually detected. Their work suggests that the thickness of the water film is temperature dependent; as temperatures rise, the water film increases in thickness. Applying glide wax to the p-tex reduces the roughness of the bottom of the ski, reducing friction, resulting in more speed per unit of energy expended (your energy and the pull of gravity). Racers like to ski on hardpack (not the same as wind slabs) or ice because with a very smooth surface, the force of friction is small, allowing for quick acceleration. In summary, when a ski slides over an uneven (rough) snow surface, frictional heating due to movement and the weight of the skier creates a thin layer of water which provides the tip and tail of the ski with a zone of reduced friction. A ski that slides over a smooth snow surface experiences a limited amount of frictional heating (because the coefficient of dynamic friction is small), resulting in a thinner layer of water at the ski-snow interface.

There are a number of additional considerations which affect ski performance, the first is snow depth and the second is the thickness of the water film. Snow depth is important because even if the thickness of the basal water film is optimal, but the ski is having to push snow out of the way, it's glide is reduced. In Spring and Summer, there is an optimal time in the morning when all of these factors come into alignment, providing some great skiing. Conversely it is possible to have too thick of a basal water film, this reduces glide because of the suction (capillary force) between the base of the ski and the surface of the water. One way to reduce this potential problem is to rill the base of the ski (introduce longitudinal grooves into the wax). This helps reduces the thickness of the water film.

Now for a trivia question, what part of a downhill ski do you think warms the greatest during a run? Colbeck and Warren (1991) took a handful of thermocouples and placed them all over the base of a pair of skis and then made a number of runs. Their data indicates that the 'warmest' part of the ski is the area just behind the heel. This is what one would expect from frictional heating, because this is the part of the ski that has the largest downward force (skiers weight). They found that this area of the ski is 1-2^{o} C (2-3^{o} F) warmer than either the tips or the tails.

Appendix There: Microphysics (continued from Chapter 5)

Condensation: vapor⇒liquid

Recall that a parcel of air is limited in the amount of moisture it can hold to a large degree (thermal pun intended), by its temperature; the warmer the air the more moisture it can hold before it reaches saturation. Cloud droplets (liquid phase only) form when the RH of a parcel reaches 100%. Saturation occurs when moisture is transported into the parcel increasing the RH, or when the parcel cools to its dew point temperature. Of course a combination of the two can occur as well.

Once a parcel reaches saturation *it does not* spontaneously produce cloud droplets. Due to molecular energy constraints, in order for water vapor to condense, some type of small foreign nuclei must be present. These nuclei are "dust-like" particles, with a typical diameter on the order of 10^{-7} m (0.0001 mm or 0.0000039 inches), and are called **cloud condensation nuclei** (CCN). Sources of CCN are small soil particles which are carried into the middle troposphere by strong surface winds. Other sources of CCN are volcanic eruptions, forest fires, decaying vegetation, as well as sea salts derived from evaporating sea spray. Small water droplets (10^{-5} m or 0.00039 inches) form when water vapor condenses on the outside of a CCN.   A parcel of air with a large number of CCN, will tend to form a cloud with a large number of small droplets. A parcel with fewer CCN will form a cloud with fewer droplets, however, these droplets are larger in size than the droplets contained in the cloud that started out with a larger number of CCN. This turns out to be an important consideration for further droplet growth. Once the RH drops slightly below 100%, condensation stops. Conversely there are times when the supply of moisture exceeds the number of available CCN, and the RH in a cloud parcel exceeds 100%. When this does occur, it is called **supersaturation**. This is an important process because it leads to very rapid droplet growth when either the parcel gains additional CCN or when larger droplets fall through the parcel from above.

Once small droplets are created they grow primarily by condensation. We have already stated that if the RH drops below 100% condensation stops. Once it stops, all of the small droplets quickly re-evaporate and the condensation cycle does not start until the air reaches saturation once again. So how do larger cloud droplets form in such an environment? Laboratory studies have shown that the water vapor pressure over a small droplet is a function of its **radius of curvature** (indicator of how curved a surface is). The radius of curvature for a flat water surface, for example, is *infinity* (i.e.-a *very large* radius of curvature), while a small cloud droplet has a *small* radius of curvature.   Samples of CCN from different types of clouds reveal a wide variety of shapes and sizes. Sea salt crystals are relatively large compared to "dust-like" CCN, in fact, a unit of oceanic air has fewer CCN than continental air. Studies have shown that the time it takes a cloud to form precipitation sized droplets is considerably less in oceanic clouds than in clouds that form over land. Large droplets typically only form when the cloud contains some larger (giant) CCN or if part of the cloud becomes supersaturated. In other words, if all of the original droplets are of roughly equal size, it is very difficult for larger droplets to develop. Most warm clouds never generate enough large droplets during their life cycle to create precipitation. Cloud droplets essentially stay suspended in the cloud because their fall velocities are so small that any upward cloud motion compensates for the downward pull of gravity.

Deposition: vapor⇒solid

The term deposition is used in the physical sciences to mean the direct transformation of water vapor into ice, without going through the liquid phase. The formation of surface hoar frost is a prime example of deposition The formation of ice crystals in clouds is very similar to the formation of cloud droplets. In order for deposition to occur an **Ice Nucleus** (IN) must be present. Ice nuclei most often consist of microscopic clay particles. Early in the 20th century researchers found that embryonic ice crystals preferred IN that had a similar crystalline structure as the ice itself. Shortly thereafter it was recognized that the structure of silver iodide closely resembled that of ice. Since that time silver iodide has been used as a cloud seeding agent. Cloud seeding was a hot research topic in the 1950's and 1960's. The impetus for this work was twofold; to control severe weather (large hail, tornados) by limiting cloud size as well as the size of hydrometeors contained within *Tcu* and *Cb*. And secondly; to "stimulate" the development of precipitation in small cumulus clouds, especially over drought prone regions. Although cloud seeding is not as popular today as it was, in large part due to legal issues, this technique is currently used to speed-up the dissipation of ice fog in some areas.

The formation of ice crystals occurs at temperatures well below freezing, in fact the preferred temperature range is around -12^o to -18^o C (10^o to 0^o F). Empirical studies have shown that cloud parcels with temperatures just below freezing have a more difficult time producing ice crystals due to molecular energy considerations, while clouds that are very cold have a difficult time producing ice crystals because of the low moisture content. Ice crystals take-on a wide range of shapes and sizes despite having similar crystalline structures. The actual shape of a crystal (plate-like, column, spherical), depends on the pressure, temperature and moisture content of the cloud in which they are forming. As with water droplets, a cloud initially containing a wide size distribution of small ice crystals, is more likely to produce precipitation sized crystals (snowflakes), because the larger crystals grow at the expense of the smaller crystals.

Freezing: liquid⇒solid

Ice crystals can also form when liquid droplets enter a region of sub-freezing temperatures. This may occur for example, when clouds containing droplets cool as they are lifted over a mountain or up a frontal boundary. Further crystal growth occurs as a result of deposition or if liquid water is present through a process called **riming**. You may be surprised to learn that liquid water can exist at temperatures considerably below freezing, when it does it is called **supercooled liquid water** (SLW). There are times when due to a lack of impurities within a droplet or the when the distribution of droplet energy restricts the formation of embryonic ice crystals, that liquid droplets do not freeze until the temperature of the water is between -10^o C and -15^{o}C (14^o to 5^o F)

Riming is a process by which ice crystals collect small SLW droplets which instantaneously freeze as they collide with the crystals (contact freezing), forming what is called **graupel**. This usually occurs when the original ice crystal is fairly large and starts to fall through the lower levels of the cloud which contain SLW. Note that the riming or icing of aircraft works on the same principal. When a plane flies through a cloud containing SLW, the wings act as giant contact nuclei, the result is a thick layer of ice accumulating on the wings. Spreading de-icer on the wings prior to take off limits the ability of SLW to bond to the wings.

Since most clouds that are capable of producing precipitation, contain both cloud droplets and ice crystals, we need to consider what occurs when both are present. Without going into the specific physics involved, we will simply state that the <u>water vapor pressure over ice crystals is lower than over liquid droplets</u>. Why is this important ? It is important because in a cloud that is <u>near</u> saturation (as most clouds are), the ambient water vapor pressure causes cloud droplets to evaporate. The water vapor that is evaporated from the cloud droplets migrates to the ice crystals where it is added to the mass of the crystal via deposition. This process is recognized to be important for the rapid growth of precipitation sized ice crystals in many clouds.

Glossary

adiabatic-- Refers to a parcel of air that does not exchange mass or any form of energy with the air surrounding the parcel. This concept is an idealization on the part of meteorologist, however it works quite well for most applications. A parcel that rises adiabatically can cool because it expands, and conversely a parcel that is adiabatically sinking can warm as a result of compression.

advection-- the *horizonta*l movement (transport) of an air mass or very large parcel.

ambient air-- Air that surrounds a designated unit of air, like a parcel, and which has different properties, such as temperature or moisture, from the parcel.

boundary layer-- A layer in the lowest part of the troposphere of variable thickness (roughly 1 km or 0.6 miles) which is influenced by the daily heating/cooling of the earth's surface. Winds within the boundary layer are influenced by surface friction.

buoyance force-- A vertical force that results from a parcel of air being either less dense than the air surrounding, resulting in rising motion; or more dense, resulting in a sinking motion.

continentality-- Regions located in the interior of continents, far removed from the ameliorating affects of the oceans. These regions experience cold winters and hot summers. (e.g. Northern Great Plans, Interior of Alaska)

convection-- A parcel that rises (updraft) as a result of positive buoyance. Convection can occur near the ground as the earth's surface is heated, or in the middle of the atmosphere when a cooler layer of air is positioned over warmer air.

coriolis force-- A force resulting from the rotation of the earth. It causes winds to deviate to the right in the Northern Hemisphere, and to the left in the Southern Hemisphere.

flow separation-- Refers to the separation of a stream of air from the ground due to a localized region of higher pressure.

front-- A boundary between a cold air mass and a warm air mass. There is a strong temperature gradient perpendicular to the front as well.

geopotential height-- Away from the surface, meteorologist use maps of geopotential height or just 'heights', instead of pressure values (isobars). These height lines are drawn from a semi-horizontal level of constant pressure, for example the 500 mb heights are taken from the height that the 500 mb pressure level is above mean sea level. High heights represent high pressure, low heights lower pressure.

geostrophic winds-- Winds in the atmosphere that occur above the boundary layer, resulting from a balance between the pressure gradient force and the Coriolis force. The direction of geostrophic winds is parallel to the lines of equal geopotential height.

Hadley cell-- A north-to-south circulation cell that as a rising branch near the equator and a descending branch around 30^{o} N/S. The Hadley Cells export energy from the tropics and transports it to the mid-latitudes in both hemispheres.

hydrometeors-- A term used to designate all types of rain drops and snowflakes.

isobars-- Lines of equal pressure drawn on a weather map.

jet streak-- The area of highest wind speeds within a jet stream. Jet streaks will move through a jet stream often producing synoptic-scale storms below.

lapse rate-- The change in temperature with height. The difference in temperature between any two levels in the atmosphere is the lapse rate. Upper-air soundings measure air temperature every few hundred meters, from which temperatures and lapse rates within the troposphere and lower stratosphere are derived

latent heat-- Process of heat energy released or absorbed in a parcel of air as a result of a phase change of water. When water vapor is transformed into a water, or when a water is transformed into ice, heat is given off. Conversely, when ice turns into water, or water into water vapor, heat is taken out of the parcel and used to make the phase change possible. A given amount of water vapor has more energy than water (liquid), which in turn has more energy than ice.

microphysics-- The branch of meteorology that studies the formation of clouds, and the subsequent development of rain and snow.

numerical weather prediction– Using computer models to solve the fundamental equations that rule the dynamics and thermodynamics of the atmosphere. Models are initialized with current data and then run into the future for a given amount of time.

nowcasts-- Refers to short-term weather forecasts that covers a period of about 6 hours. Nowcasts are generally only issued when weather conditions are changing rapidly.

occlusion-- A type of front in which the cold air has completely wrapped itself around the low pressure center, lifting all of the warm air above the surface.

overrunning-- Process in which warmer moist air moves over the top of cooler dry air. Given enough vertical lift, during the winter this often leads to the production of snow. A common event in or near mountainous terrain.

pattern recognition-- A methodology used by weather forecasters that utilizes the forecasters past experience with a given weather pattern, to predict what is going to happen when that 'same pattern' occurs again.

pressure gradient force-- A force resulting from high pressure in one location and low pressure in and adjacent location. Motion in the absence of any other force is from high to low pressure.

rain shadow-- A region downwind of a mountain range that receives smaller amounts of rain (or snow) when compared to the upwind side of range. This occurs because the majority of the precipitation has been forced out of the clouds over the mountains where air is rising.

saturation-- Air is said to be saturated when it contains the maximum amount of water vapor it can hold for a given temperature. When air is saturated its Relative Humidity is 100%.

sea surface temperatures-- Water temperature at or very near the surface of the ocean. SST's are measured either by ships and buoys, or estimated by sensors mounted on satellites.

scattered or scattering-- Refers to the absorption and re-emittance of electromagnetic radiation by various types of gases in the atmosphere.

shortwave radiation-- Electromagnetic radiation that is visible to the human eye.

snowline-- A transient line that separates an area of snow from snow-free ground. The snowline can vary considerably from one storm to the next. In general, during the summer the snowline gradually moves to higher elevations.

storm track-- Refers to the movement or concentration of synoptic-scale storms, usually along the polar jet stream.

supercooled liquid water-- Water that has a temperature below freezing yet it remains a liquid. The reason this can occur is that in order for water to freeze, it needs to some type of foreign material (aerosols, dusts) or what is called an ice nucleus to initiate the freezing process. If foreign material is absent from a parcel of air, the temperature of water can reach well below freezing. Ice crystals that fall through a layer of SLW, are often rimmed, because the ice crystal acts as an ice nuclei.

temperature gradient-- A region in which there is a large temperature difference. For example, if its 22^{o} C in Seattle and 18^{o} C, then the temperature gradient is 4^{o} C per 285 km. Essential it is the difference in temperature over some horizontal distance (referred to in this book as 'temperature contrast).

temperature inversion-- A layer within the atmosphere where the temperature increases with an increase in height. Inversions typically form within one or two kilometers of the ground and may persist for several hours or be semi-permanent depending on the situation.
trade wind inversion-- Is a persistent temperature inversion which is found over much of the sub-tropics at an altitude of 2000-3000 m (6500-9800 ft) above the surface of the ocean.

tropopause-- Divides the troposphere (lowest section of atmosphere) from the stratosphere.

upper-air data-- This data consists of wind speed, wind direction, temperature, and relative humidity taken every few hundred meters during a weather balloon ascent. An additional name is sounding data. The instrument package attached to the balloon that makes the measurements and transmits data back to the ground station is called a radiosonde or rawinsonde.

virga-- Rain that evaporates or snow that sublimates (changes from solid directly into water vapor) before it reaches the ground. Often viewed from a distance as a dark shaft extending below cloud base.

Recommended Reading

Barry, R.G. 1992. *Mountain Weather & Climate*. London: Routledge. 2nd edition. This book was written for meteorologist but I would recommend it to anyone who is serious about mountain meteorology.

Price, L.W. 1981. *Mountains & Man* Berkley, CA: University of California Press. A book that covers a wide range of mountain environment issues, including mountain weather and climate. Can be found in libraries.

Wallace, J.M. and P.V. Hobbs. 1977. *Atmospheric Science: An Introductory Survey*. Sand Diego, Ca: Academic Press. This is one of several standard college level textbooks. Even though it has some advanced material, there are plenty of topics that a serious student of mountain weather could benefit from. This book can be found in many college bookstores.

Whiteman, C.D. 2000. *Mountain Meteorology: Fundamentals and Applications*. Oxford, England: Oxford University Press. This is a excellent book that makes good use of graphics and photos.

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