

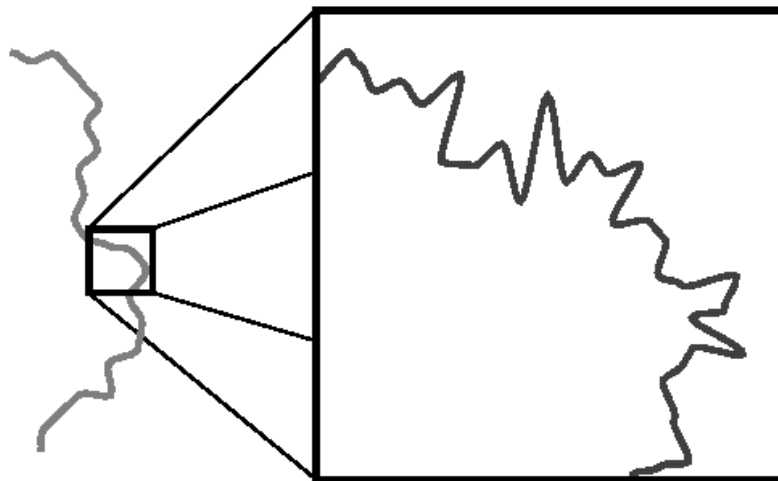
Weather Concepts for Free Flight

By John Matylonek, USHPA advanced instructor

Weather is a complex topic. Whole branches of mathematics have been developed in its' prediction. Analytical pilots can easily get caught up in the details, missing the forest for the trees. Ultimately, local wisdom and "knowing directly" what happens, over years of experience at the local site, becomes much more important than theory. We will eventually get to this level of discernment too. But for now, we simply want to eliminate unnecessary driving, or frequency of attempts to fly but aborted due to conditions. Fortunately, weather products and tools on the web have done much increase our to predict the weather. The prediction products found on the internet almost create the weather for us on the computer. All we need to do is synthesize the information to form an accurate assessment of the day's potential. However, use of these tools requires an idea of how weather works and some predictive principles. This document covers the first point. It complements the Wondrous Wind lecture by Michael Robertson also found in this course.

Fractal scales

If you haven't kept up with the universal truths lately, the world is considered 'fractal'. The patterns that we see at large scales are replicated at smaller scales. For instance, the craggy coastline gets craggier the closer you look it at – from orbit on down to the local harbor, to the specific beach. Or, if we look at tree, we notice that small branches duplicate the larger branches only they are smaller. The coast or the botany of a tree, like today's weather, is a superposition of all its' scales. But unlike the coast or a tree, the weather changes much more quickly, and so requires daily re-mapping and analysis. Noticing these same patterns from higher to lower scales and their relative strengths can simplify your understanding of global, regional and local weather patterns.



Graphic from "How long is the coast of Great Britain?"

Forecasts and Scales

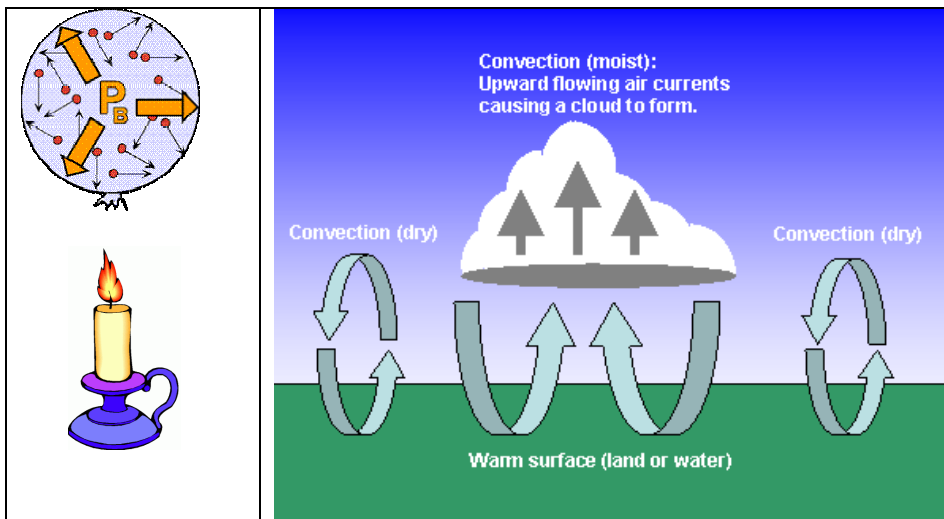
The superposition or layering of regional, local and site specific weather information provides you with an accurate picture of the weather. The interaction of regional, local and site weather will determine the major cause(s) of today's conditions. Determining which of these factors that will dominant is the trick in forecasting. Since heating is cause of the wind lets start at smallest scale first - the heating of a small volume of air. Later, we will use these same principles to describe weather phenomena at larger scales. The strategy for looking at the weather is presented in the **Prediction Series Examples** module of this course.

Principles versus Prediction

Prediction products on the web assume a basic knowledge of terms of basic meteorology. This manual and the Wonderous Wing lecture should provide most of the information you will need to know about the science of weather. However, each prediction product has its own design that will need to be studied. This information is in the **Prediction Tools module**. Also, examples of how to interpret all the conflicting reports will be provided in the **Prediction Series Examples**. If you are really serious about how to predict weather, the *optional module* that links to the University Corporation for Atmospheric Research **MetEd Tutorial** website is an advanced study and quiz system.

Differences in heating and density causes convection

Most materials expand when they are heated. They contract when they are cooled (water is an exception). When air is heated and expands, the density (mass per unit volume) decreases, becomes more buoyant, and rises. When air is cooled and contracts, the density increases, becomes less buoyant and sinks. Thus, you can watch a feather rise over a indoor radiator and then fall, following the rising and sinking air in the room. Also, you can watch a hot air balloon rise but eventually descend again as it cools. This happens at all scales on the Earth – from global circulations to your own backyard.



Graphic from www.weatherquestions.com

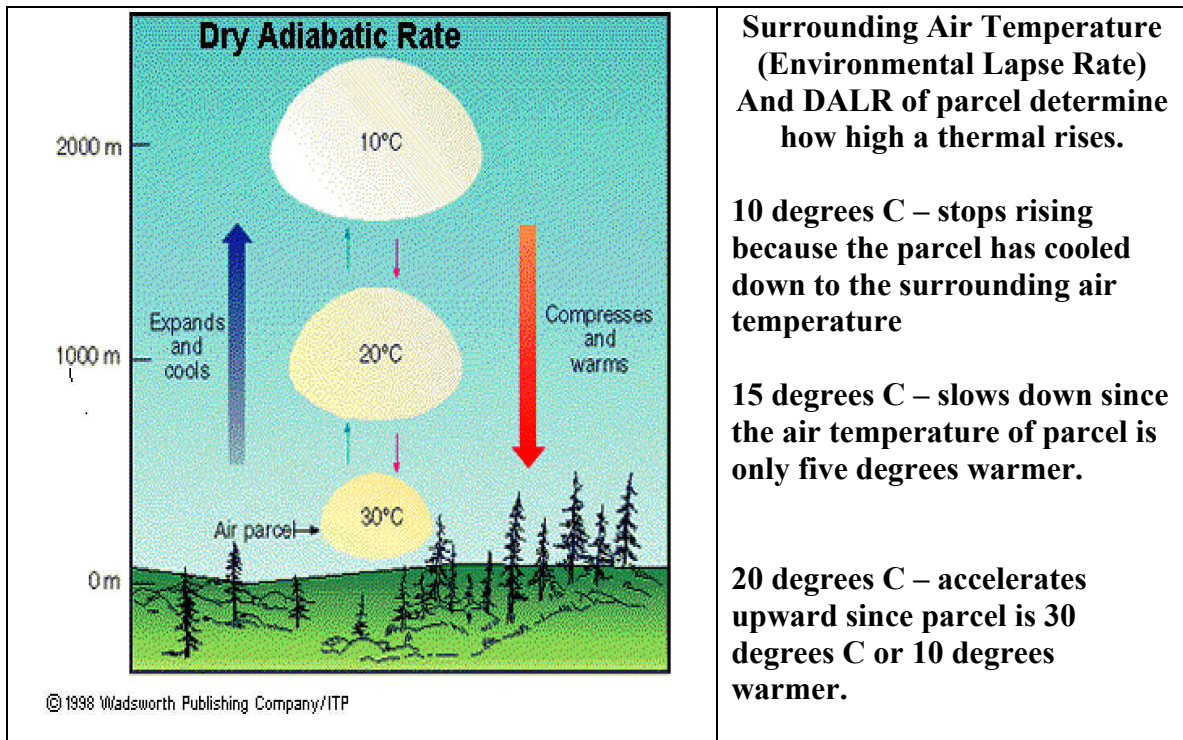
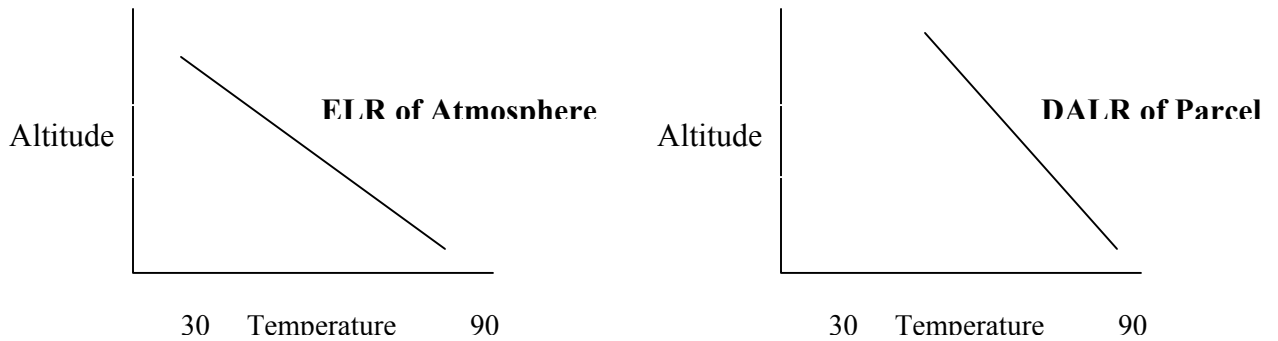
This **convection is enhanced** when air includes water from evaporation, because water *decreases the density* of the air. That is because water molecules are lighter and displace relatively heavier air molecules. Water contain two very light hydrogen atoms and one heavier oxygen H_2O . Air, without water, is mostly made of nitrogen, N_2 and O_2 – four relatively heavier atoms. Clouds and fog are simply the steam (small water particles) that condense from gas to liquid, out of a column of hot air that has risen to a height in the atmosphere where the temperature decrease causes change in state from gas to liquid. This is called the **dewpoint**. Sometimes, the dewpoint is very near the surface, so instead of clouds we get fog. So, air can rise because it could be heated or be saturated with water or both.

Lapse Rates – The Change in Temperature with Altitude

The temperature of the air normally decreases at around 5.0 F degrees per one thousand feet of altitude. So, as long as the hot air from the surface remains hotter (as it cools down) than the surrounding air, it will rise. It will also expand, as the air around gets cooler than the parcel of air going up in it. Of course, there comes a point when the air from the surface cools down to the surrounding air and it stops rising. Or, the air meets a cooler temperature at elevation at which the water in it condenses (the dew point) and rises much more slowly.

The temperature difference between the surface and some height in the atmosphere is called the **environmental lapse rate**. The greater the **ELR** (the difference) the faster a heated parcel of air rises. The **Dry Adiabatic Lapse Rate (DALR)** is the rate at which an air parcel from the surface cools with rising.

When the air condenses water to form a cloud there is a release of heat. This cools the parcel of air further and creates different rate of cooling of the parcel. This is called the **Wet Adiabatic Lapse Rate**. Since we don't fly into the clouds, we are not too concerned about this phase of the thermal as it rises.

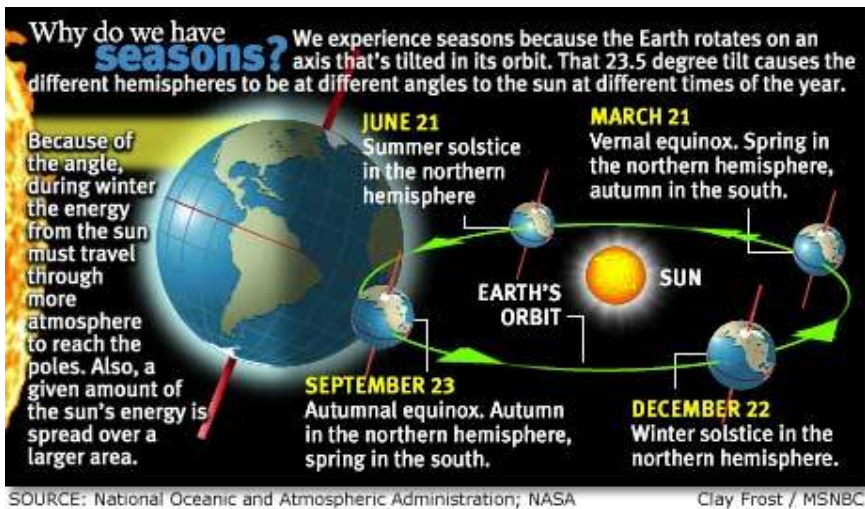


Seasons

Differences in temperature occur laterally over the earth at different latitudes. The temperature differences on earth causes differences in density and therefore convection cells like one pictured above. But they are on a grand scale.

We have three great major air masses in each hemisphere on the earth as defined by temperature and density differences due to differential heating. Since, they have different temperatures and densities and they act as independent masses that “compete” for dominance on a seasonal basis. The changing volume and extent of these air masses cause the seasonal temperature, wind direction, and precipitation differences yearly.

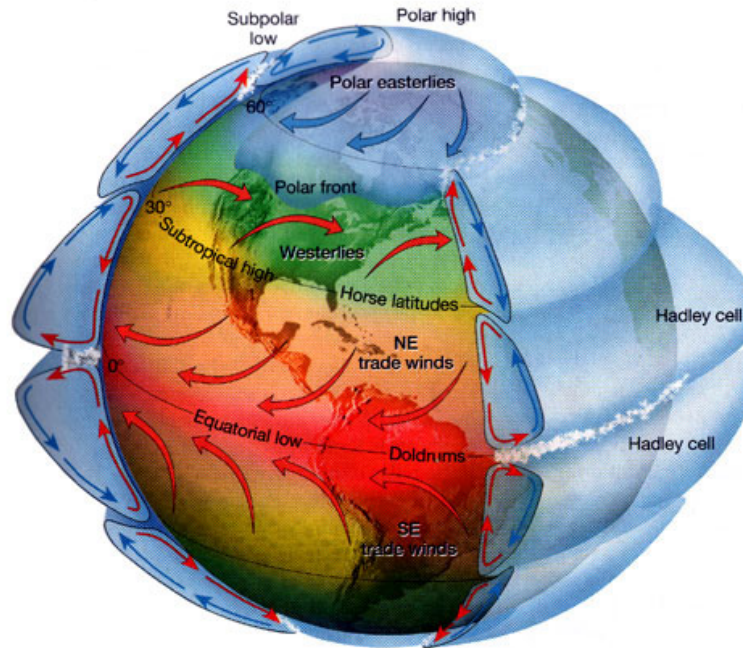
Since the earth acts like a spinning gyroscopic toy top, the vertical spin axis (leaned 23.5 degrees) stays pointed in the same direction as it revolves around the sun.



The boundaries between the rising and sinking air from the equator form "convection cells" very much like the one defined by the rising and falling bubbles in a boiling pot of water. There are three great global convection cells between the equator and the north pole.

Global Winds and their Direction

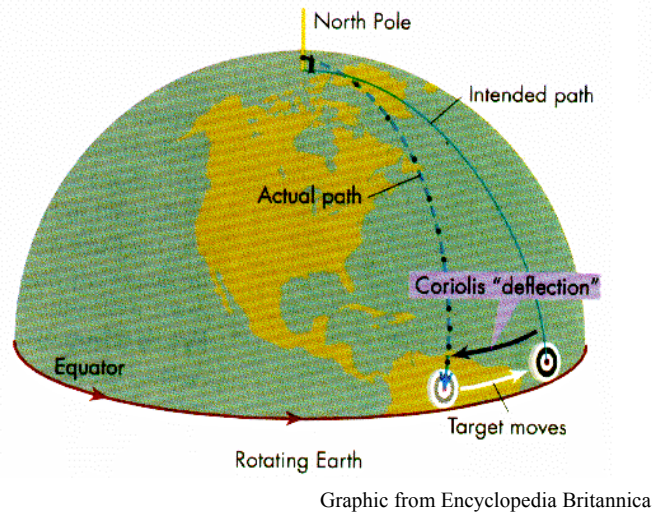
The downward moving air from one of the great equatorial convection cells eventually finds the earth at a higher latitude and must be deflected horizontally. This is the cause of major consistent wind patterns on the earth at different latitudes and altitudes. In particular, the Westerly Trade winds and form near the earth's surface and above the Hadley cells, respectively, to direct weather systems from west to east in the US.



Graphic from Lyndon Stat College of Survey of Meteorology 130
<http://apollo.lsc.vsc.edu/classes/met130/>

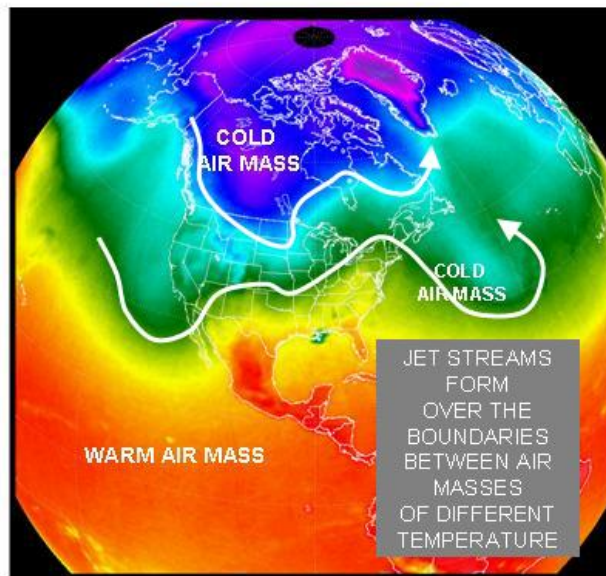
The direction of these global winds is caused by the independent movement of the air and the earth. An example will clarify this. Imagine an artillery cannon at the north pole aimed at a target 6000 miles away on the equator. The artillery shell shot would seem to curve in the air as a earth rotates underneath it, if the gunner did not lead the shot many miles.

Global winds curve to the right in the northern hemisphere (as seen from above the north pole) and left in southern hemisphere. This is called the **Coriolis Effect**.



Jet Streams

The interface between the convection cell created at the temperate latitudes and polar latitudes forms the "jet stream". Thus, the size and volume of the global cells change with differential heating, the cells expanding and contracting with the seasons. The "jet stream" is the interface between the polar cell and temperate cell. Of course it tends to have a more southerly position in the winter and more northerly position in the summer. Its ever changing position over North America can tell us which air mass is dominating our regional weather.



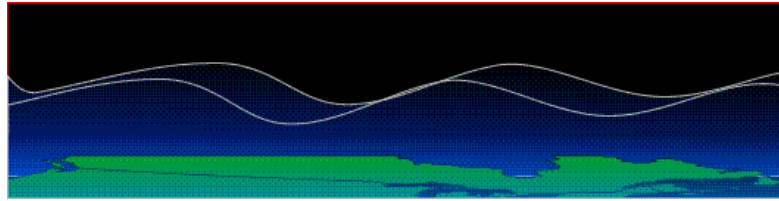
Graphic from www.weatherquestions.com

The jet stream position is extremely important in long term forecasting (5-10 days) because the jet determines what air mass is dominant (warm or cold). Also, when the jet stream is overhead it tends to bring frontal passage and unsettled weather.

The Jet Stream positioning forecast often provides assurance that the weather will indeed be warmer or colder and/or will be stable. Here is the positioning forecast for the next three days – Jet [Stream Position Forecast](#). The time at which it is not directly over Oregon tends to bring more stable weather.

The Ocean of Air

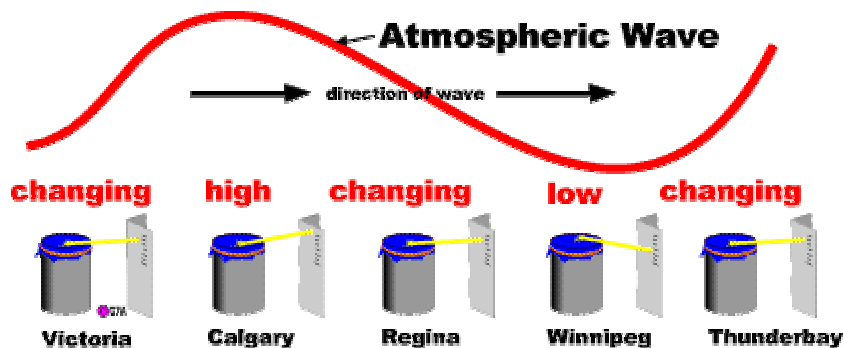
On the surface of the Earth we live at the bottom of an ocean of air. And just like any ocean, the ocean of air has waves rolling along the top. Of course, unlike the surface of the ocean, the atmosphere has no sharply defined "edge" or "top", but it still has waves on it nonetheless. For example, we could define the "top" as the layer above the Earth's surface where the atmospheric pressure is exactly 2 kilopascals (2 kPa).



Since air has weight, we can measure the pressure of the weight with instruments. As the waves pass overhead we can observe their passage as changes in barometric pressure on the Earth's surface.

It is the passage of these waves that is responsible for the changes in weather that we experience each day. When plotted on a surface weather map, these elongated pressure patterns resemble mountain ridges on terrain maps. Meteorologists therefore refer to them as *high pressure ridges* or simply *ridges*.

Here are the pressure differences across Canadian cities during a particular passing wave of air.

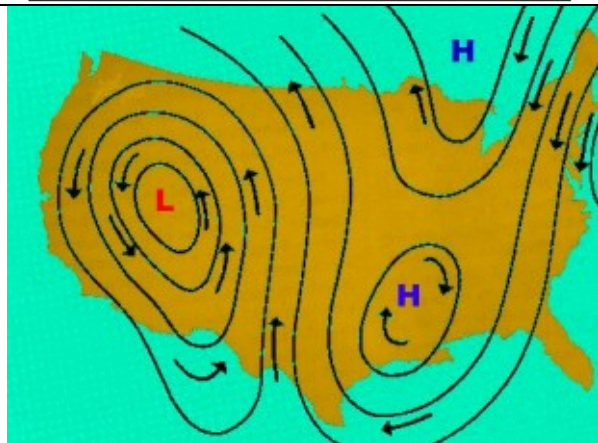
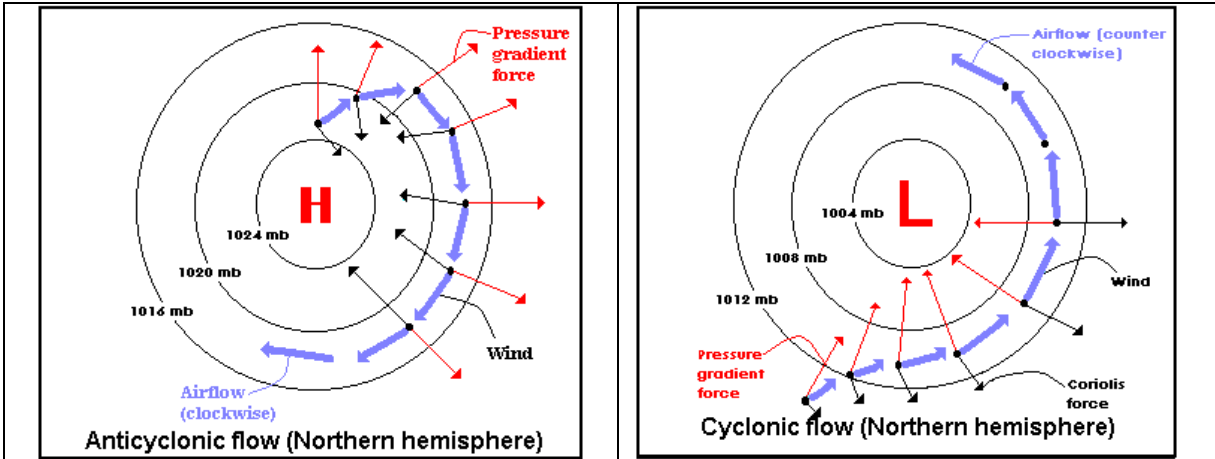


By carefully monitoring changes in a barometer one can make 12-hour weather forecasts which are about 90% accurate in terms of general weather conditions. **Airport weather observing stations (AWOS)** provide hourly barometric pressure readings that not only provide a big picture of rising clouds, more visibility and less rain, but also if the wind speed will decrease or increase or even change directions. Let us now examine how pressure differences affect the winds and rain.

Regional High and Low Pressure Waves

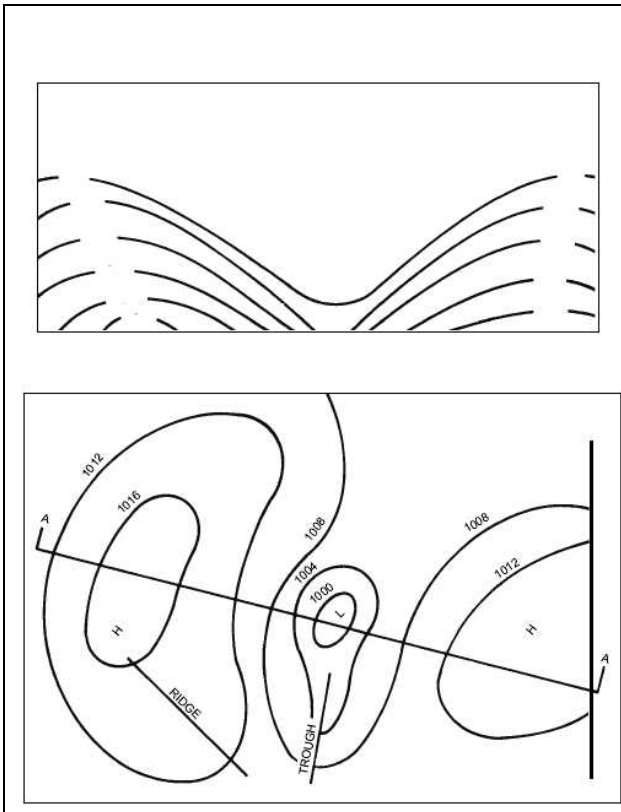
<p>Graphic from Wikipedia en.wikipedia.org</p>	<p>Imagine being buried in a sandbox. If somebody piles more sand on top of you it will feel heavier. If someone removes sand from the pile it will feel lighter. This is pressure rising and falling. But, every time someone piles more sand on top of you, the sand doesn't stay at the very top of the pile. Some of it cascades down the sides of the pile. Some of it settles within the pile too. It always takes a little more sand to build the height of the pile at the same rate. This is because the piling is countered by gravity. The same thing happens with air. It takes a lot of energy and volume of air to pile the air past the 2 kilopascal pressure height (pressure altitude) before it cascades down and settles within.</p>
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As the air slides off the crest of the “high” it travels down and out, just like sand particles on a pile of sand. The “piles of air” in the atmosphere are very large. The cascading air molecules movement is independent of the earth’s rotation and turns the air (wind) in reference to the earth’s surface. Thus, the **Coriolis Effect** deflects the wind right from a “high” in the northern hemisphere.



Graphic from Weather Phenomenon and Elements
<http://www.islandnet.com/~see/weather/elements/high.htm>

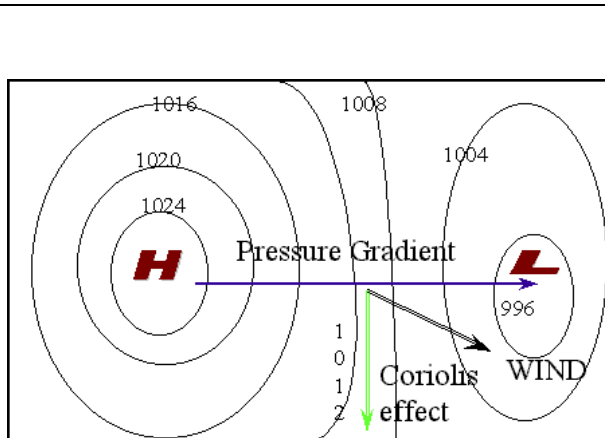
Like the Chinese ying and yang symbol or the crest and trough of an ocean wave, an adjacent “high” defines the “low” next to it. So, from the perspective of the “low” the air is deflected to the left. The lines on the map below are represent lines of equal pressure called **isobars** – just like lines of equal heights on a topographic map. Thus, we have a bowl centered on the western US and mound centered on the southeastern US in the graphic below. The movement of each cell or ridge causes the wind direction to change at any specific location.



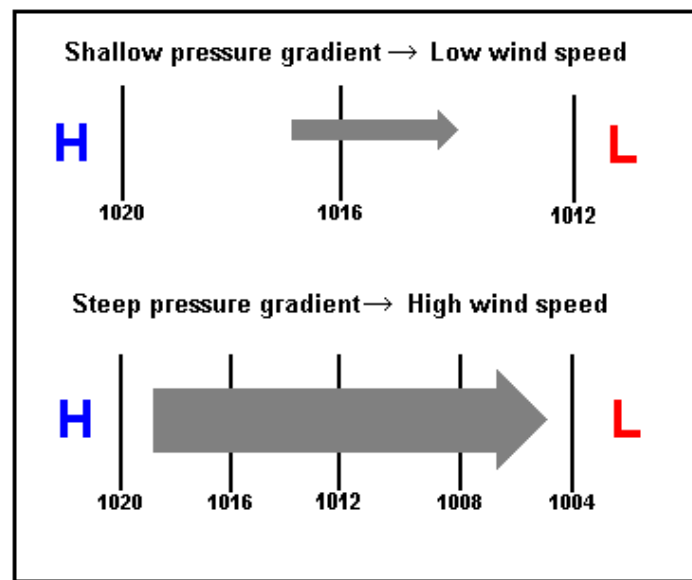
Cross Section of Adjacent Highs

It is important to be able to visualize air flowing around highs, lows, troughs and ridges in three dimensions, as if the atmosphere were actual terrain. Here is a cross section of a low centered between two highs. Imagining a ball rolling to the left down high and spiraling right into lows often helps. A greater pressure gradient creates a faster wind. As the air flows down hill – from higher pressure to lower pressure as it crosses each **isobar** on its way down to center of the bowl. Just like a topographic map, the closer the isobars are spaced the faster the wind will flow downhill because the pressure gradient is steeper.

Pressure Gradients and Wind Strength



Graphic from College of Alameda Physical Geography
Rita Haberlin, Instructor <http://members.aol.com/pakulda/pwvptnts.htm>



Graphic from: PHYS-255 Meteorology UW-Stout Physics Department

Observing the movement of high and lows and their changing pressure gradients and assessing their relative strengths is very useful in predicting what is going to happen at the flying site.

Both, the spacing and difference in pressure affect how much wind there will be.

The trend of the spacing and absolute differences in an isobar forecast map will tell you if the wind will increase or decrease. Although other factors affect the wind speed (notably the constriction of wind by geography other weather systems and thermals), the following is a useful rule of thumb over a 100 sq mile area in the Willamette Valley.

Difference	Wind Speed
.01	3-5 mph
.02	5-10 mph
.03	10-20 mph
.04	20-30 mph

How Changing Pressure Affects the Weather

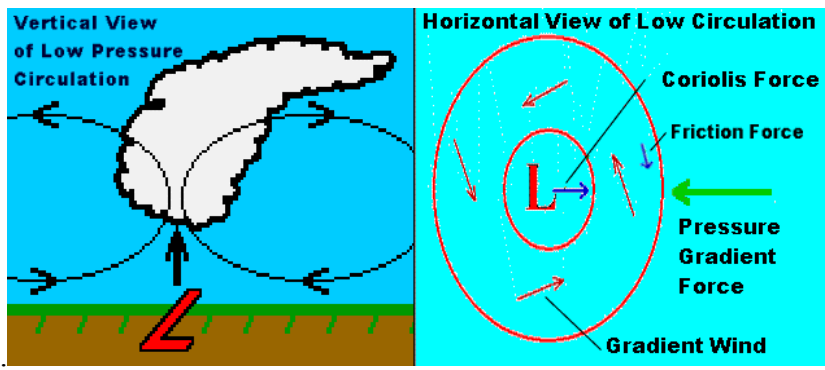
Under a low pressure depression the weather is stormy. Under a high pressure the weather is fair.

When the barometer is "falling" (changing), and pressure is becoming lower the weather will get worse within the next 12 hours. So, why does low pressure bring rain and wind and high pressure fair weather?

Air cascading down the low pressure "bowl" meets at the surface and collides with air coming from all sides of the "bowl" thus forcing itself up in an ascending air column. This column rises and flows out and away from the rising core. The "steepness" of the bowl determines how fast it flows down and how fast it ascends, just like particles of sand down a steeper slope. This steepness is called the **pressure gradient**.

As this air reaches the bottom of the bowl, it has no place to go but up again. Air moving upward cools by expansion, usually reaching its **condensation level** (the temperature point at which gaseous water turns to steam) along the way. Clouds form at the condensation level and extend upward in the atmosphere. If conditions are right, precipitation develops as more and more water vapor is transformed to larger liquid water

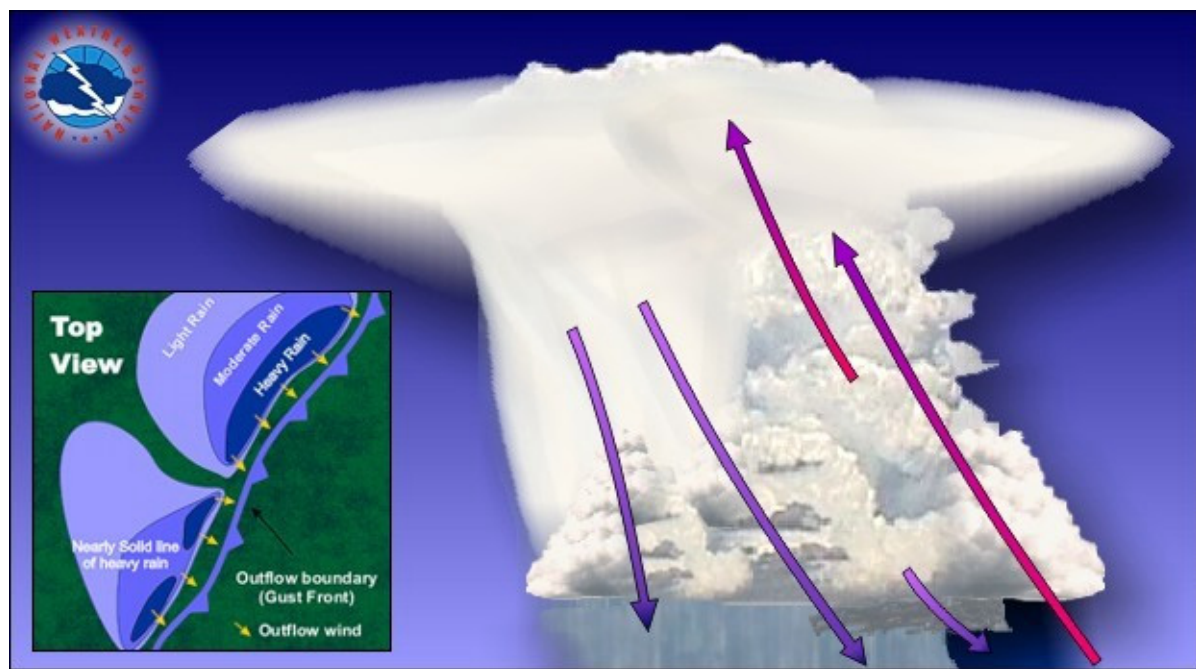
or ice crystals that eventually fall earthward. The presence or approach of a low pressure cell signals cloudy and wet weather.



Graphic from A Weather Glossary www.weatherquestions.com

<p>Continued expansion of air creates lower pressure at the surface.</p>	<p>When the combination of these processes removes air faster from the surface than it can be replaced by the converging inflow, the temporary mass deficit in the air column lowers its weight, and thus reduces the surface pressure, causing it to become even lower than the surrounding atmosphere. There is a positive feedback effect. The creation of the low pressure cell creates the conditions for even more low pressure to develop. It feeds on itself.</p> <p>Graphic from University of Illinois WW2010 Weather Tutorial</p>
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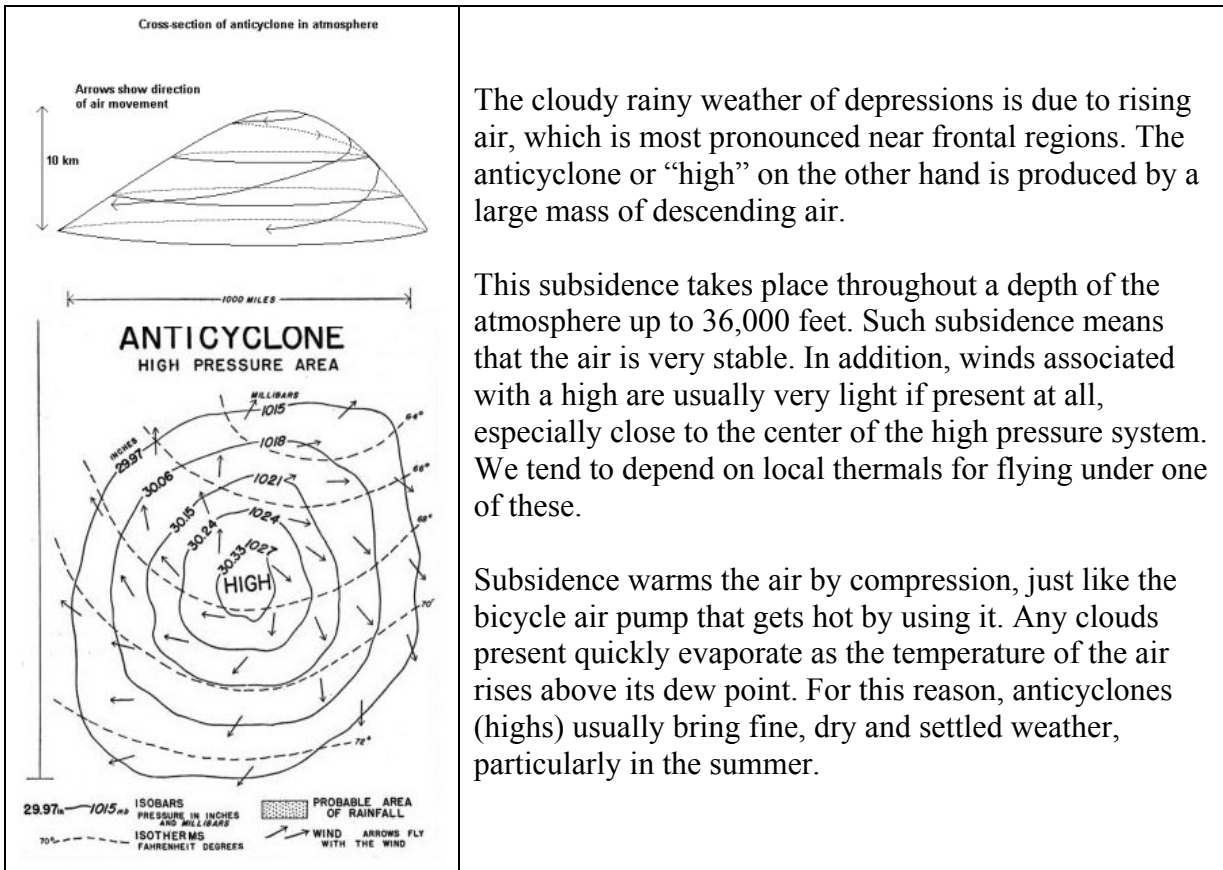
Eventually, this process leads to squall lines, thunderstorms or even hurricanes



Graphic from Jetstream, an online weather school

High Pressure

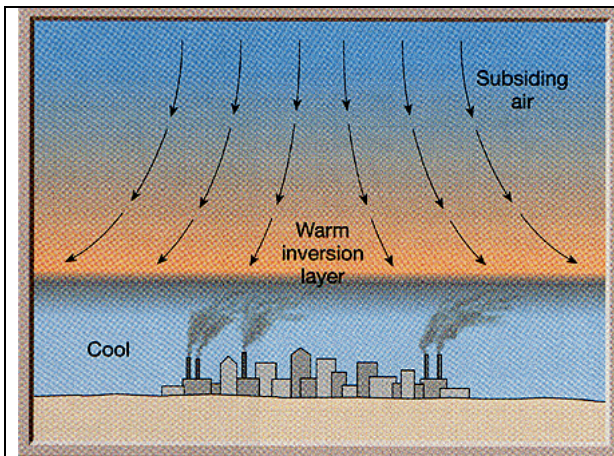
When the barometer is "rising " (the pressure is becoming higher), and pressure is increasing the weather will get much better within the next 12 hours. Because the air in a high sinks through a deep layer of atmosphere – just like the settling sand within our sandbox pile, the formation of clouds and precipitation are greatly inhibited. Generally if clouds do form, they are spawned by strong smaller scale solar heating of the surface and are small and of limited vertical extent – usually *fair weather cumulus*



The cloudy rainy weather of depressions is due to rising air, which is most pronounced near frontal regions. The anticyclone or “high” on the other hand is produced by a large mass of descending air.

This subsidence takes place throughout a depth of the atmosphere up to 36,000 feet. Such subsidence means that the air is very stable. In addition, winds associated with a high are usually very light if present at all, especially close to the center of the high pressure system. We tend to depend on local thermals for flying under one of these.

Subsidence warms the air by compression, just like the bicycle air pump that gets hot by using it. Any clouds present quickly evaporate as the temperature of the air rises above its dew point. For this reason, anticyclones (highs) usually bring fine, dry and settled weather, particularly in the summer.

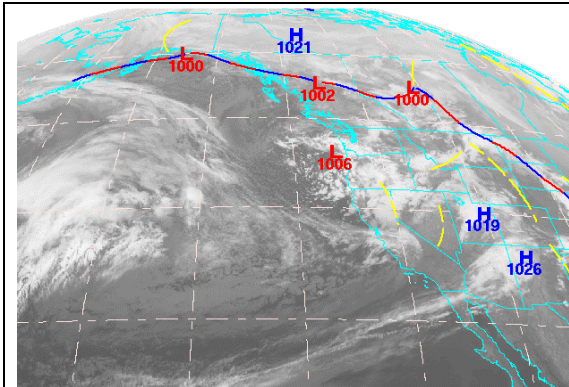


Graphic from Lyndon State College Survey of Meteorology

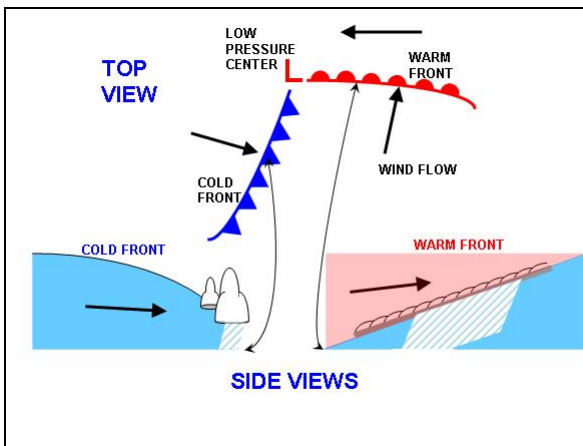
Sometimes, subsidence and compression of the air can produce a temperature inversion at one or two thousand feet above the Valley. Such phenomena act as a cap to rising air heated by the ground under the influence of the Sun, preventing extensive cooling and cloud formation. Unfortunately, if the air is moist below the temperature inversion, a dreary formless layer of cloud can form which becomes difficult to disperse owing to the light winds. Such debilitating weather is common in winter when the Sun's radiation is too weak to burn off the cloud layer.

Frontal Passage

A front is defined as the transition zone between two [air masses](#) of different density. Fronts extend not only in the horizontal direction, but in the vertical as well. Therefore, when referring to the frontal surface (or frontal zone), we referring to both the horizontal and vertical components of the front.

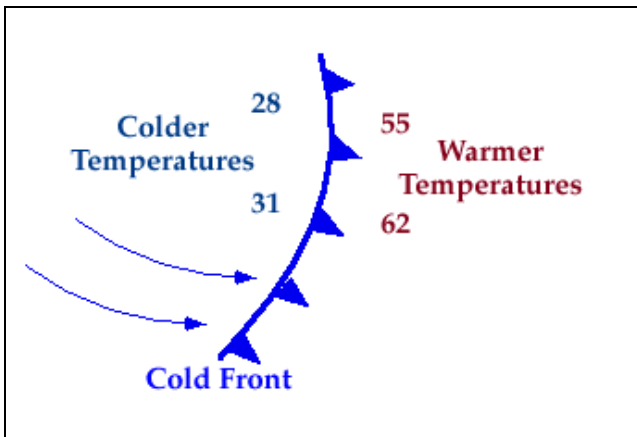


Here is a satellite image of the temperate zone air mass battling the polar air mass. Note that at some places along the boundary the temperate air mass is winning with warm front (red lines) passage to the north. Other areas along the boundary the cold air mass is winning with cold front (blue lines) passage to the south



Low pressure systems are associated with frontal passage because the low tends to draw air into itself from all sides. If the low is centered between two very different air masses (as above) the low will create both cold and warm front passage. Most of the time the difference in air masses is not that different so we get only one or the other. Let's look at both kinds of fronts as they affect Oregon.

A cold front is defined as the transition zone where a cold air mass is replacing a warmer air mass. Regional cold fronts generally move from west - northwest to east - southeast. The air behind a cold front is noticeably colder and drier than the air ahead of it. When a cold front passes through, temperatures can drop more than 15 degrees within the first hour.



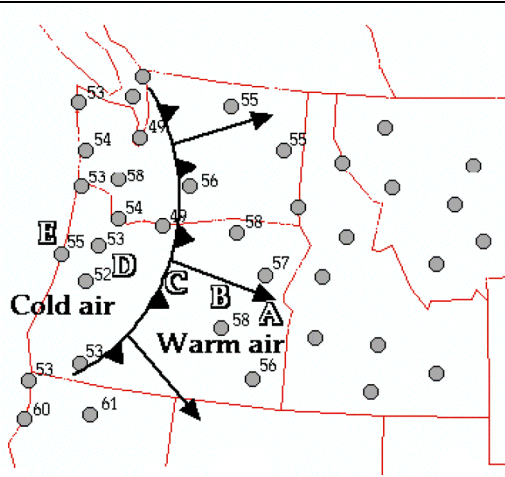
1. Well ahead of the front (A). This is the same position as D on the warm front diagram.

Temperatures are relatively high (in fact, the highest winter temperatures in Oregon nearly always occur at these prefrontal locations).

Winds are from the south and can be quite strong. Skies are partly cloudy to cloudy.

There may be some rain, but it is Probably intermittent.

Summer-time cold fronts are less common the winter-time warm fronts



2. Approaching the front (B). Winds are still from the south, and stronger. Temperatures have changed little. Thick clouds have approached from the west. Rain may have begun.

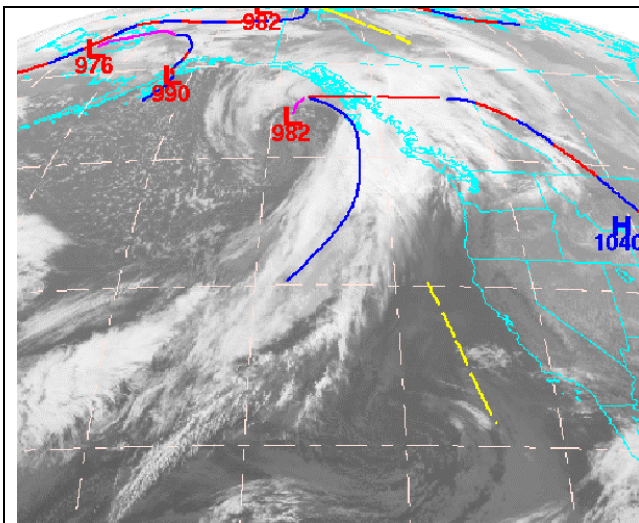
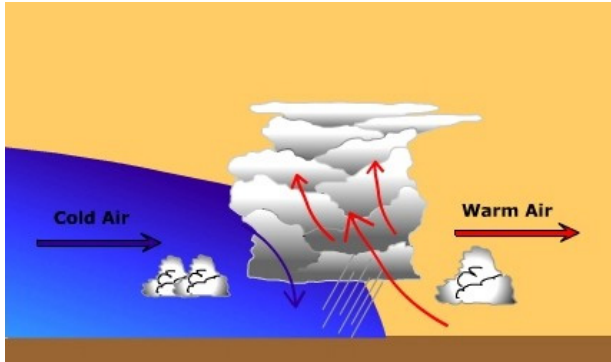
3. Very near the front (C). Winds have continued to strengthen, but temperatures are unchanged. Clouds have gotten thicker and darker. Rain (or snow) has become very intense.

4. Behind the front (D). A wind shift occurred as the front passed over earlier, and winds are now from the west or northwest. Temperatures have dropped markedly, and the air is drier. Intermittent rain/snow showers continue, but sun breaks (in daytime) may occur.

5. Well behind the front (E). Winds continue, but are not as strong. Showers have become less frequent. Sun breaks are more common. Rainbows are often spotted.

Flying sites now optimized:

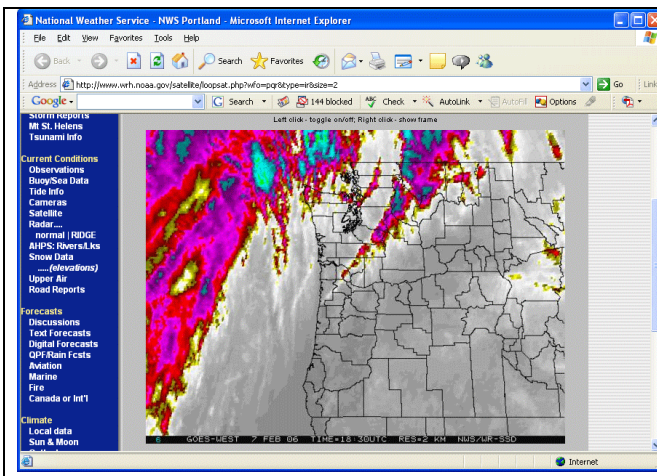
- Andersen's (Cape Lookout)
- Prairie Mtn (Alsea)
- Pine Mtn (Bend)
- Cape Kiwanda (Pacific City)
- Woodrat Mtn (Jacksonville)
- Dog Mountain Morton, WA



This is a visible satellite image (as if we using our eyes in space) of a cold front bearing down on Oregon.

Note the extensive clouds associated with the front. But also note the clear area between Oregon coast and the clouds.

This observational tool will allow you to decide if there is enough time before the front to fly, especially if another front had just passed through and it is now post-frontal.



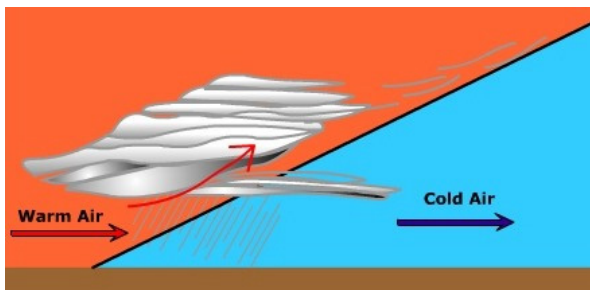
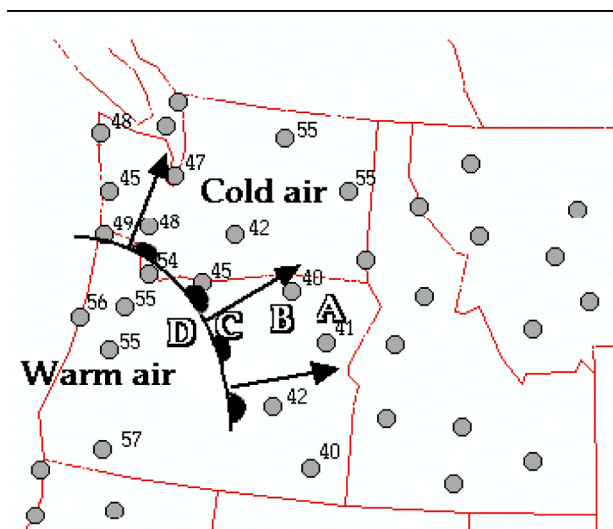
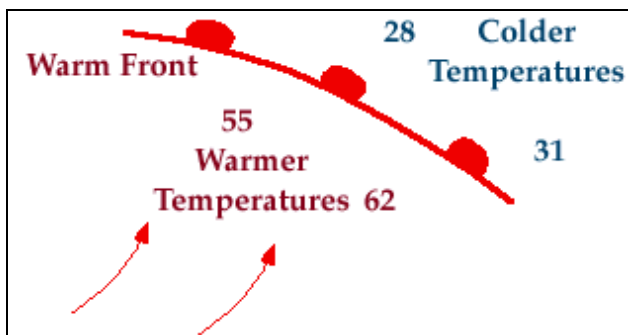
Here is an infrared image of the same front bearing down on Oregon.

Infrared measures the temperatures of clouds. The red areas are the coldest and therefore the highest clouds. Since the stormy weather is associated with big thick clouds this a great tool to determine when the worst of it will be finally on the coast.

Here we still have a whole day till the front arrives

Warm fronts

A warm front is defined as the transition zone where a warm air mass is replacing a cold air mass. Warm fronts generally move from southwest to northeast and the air behind a warm front is warmer and more moist than the air ahead of it. When a warm front passes through, the air becomes noticeably warmer and more humid than it was before.



Note that a warm front's interface angle is less steep. This causes wider area effects over a longer period than in the case of a cold front passage. This and the consecutive passing of multiple warm fronts in the winter is cause of much of our incessant rainy weather.

Graphic from Oregon Weather: A State of Extremes

Warm fronts in Oregon are characterized by S-SE winds before passing changing to S-SW after passing with steadily warming temperatures and intense increasing precipitation. Winter-time warm fronts are dominant

1. Well ahead of the front (A). Winds are generally from the southeast, and increasing. Temperatures are cool. High clouds may appear overhead or on the horizon.
2. Approaching the front (B). Winds are still from the southeast, and stronger. Temperatures have changed little. Clouds have gotten lower, and light rain has begun.
3. Very near the front (C). Winds and temperatures are unchanged. Clouds are lower still, and light rain continues (and increases in intensity).
4. Behind the front (D). A wind shift occurred as the front passed over earlier, and winds are now from the south-southwest. Temperatures have gone up markedly, as has the humidity.
5. Once we are fully embedded in the warm air mass and it is not directly followed by another wet warm front, (during spring and fall) the precipitation can become more intermittent, sun breaks can occur and even clear-up leaving the remnant SW wind

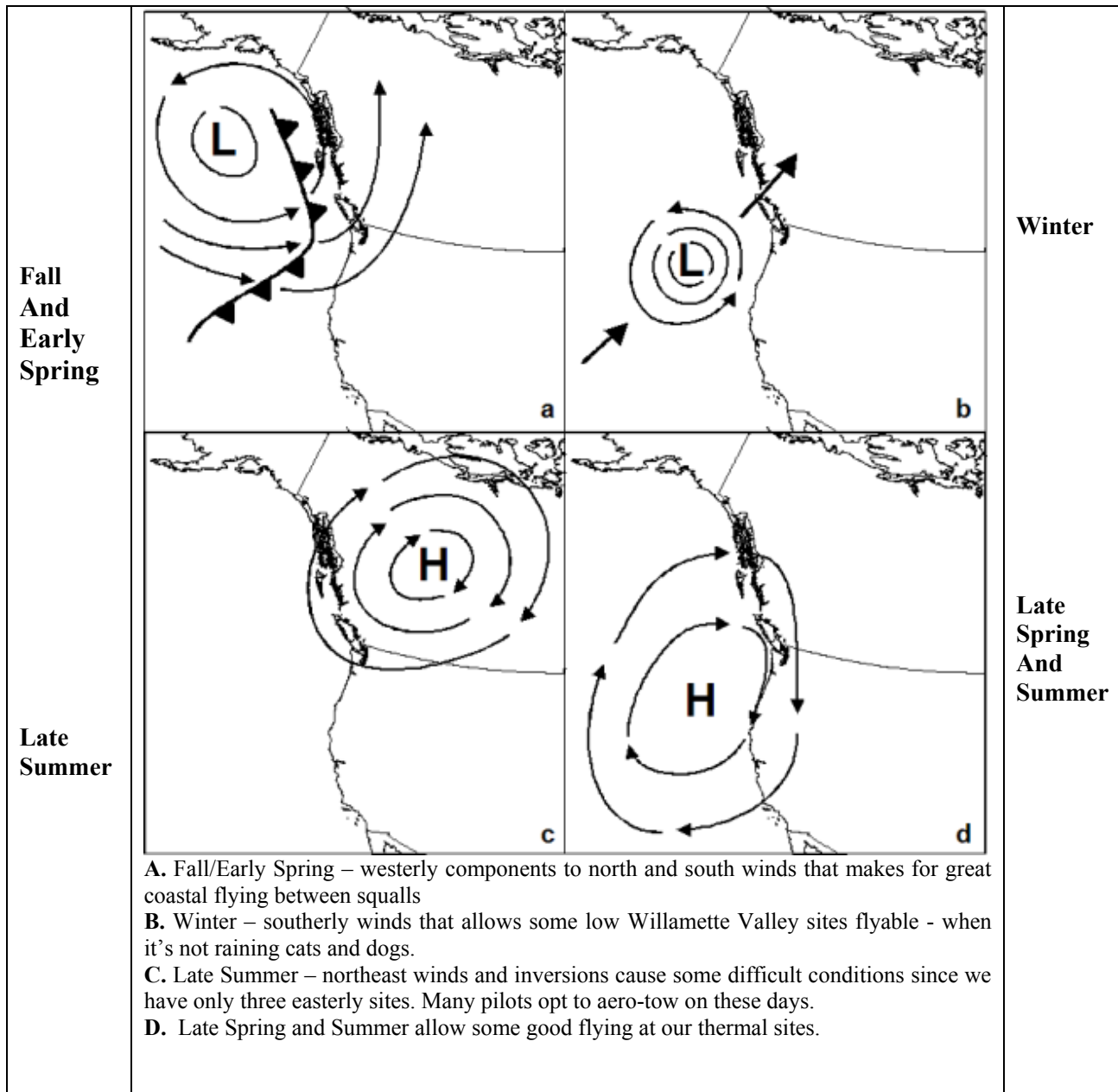
Flying sites now optimized:

Oceanside
Sollie Smith
Newberg
Sea Lion Caves

Reference: Ahrens, C. Donald, "Meteorology Today," Fifth edition.

Seasonal Variability

During the late summer in Oregon, the seasonal heating creates a consistent and dominant regional high pressure off the coast of Oregon, Washington and southern British Columbia (D). This positioning creates a dominant northerly flow for weeks and months. Both cold and warm front passage is inhibited during this time. This fair blue sky clear weather with inversions, low lapse rates and northerly winds. This **inhibits** flying at our thermal sites and westerly launch sites. If the high pressure moves inland, an easterly component develops and off shore flow (wind coming from land onto the sea) develops (C). Many of our sites do not have easterly launches so the flying is greatly inhibited. Exceptions include **Cliffside** in the Eastern Gorge, **The Flying M** ridge line near Newberg and **Hobart Butte** near Cottage Grove. This last site is where the local topography steers the northeast winds into more northerly direction into its' face.



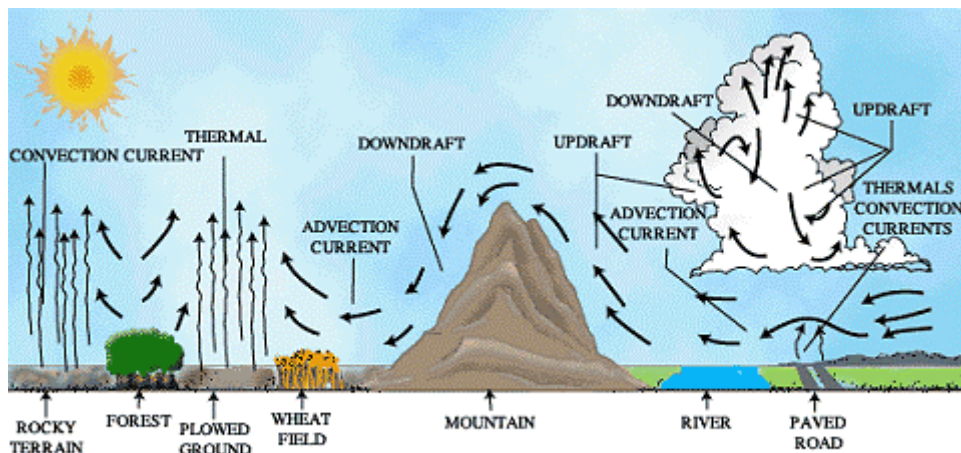
As autumn or spring approaches there are competing systems of high and low pressure. The sea breeze effect is weakening. There is much variability through regional frontal passage, migrating local cells and many changes in wind direction. During this time, the regional instability causes favorable westerly components to the north and south winds, making for great flying again (A). However, taking advantage of the window of opportunity during these rapid changes requires extra vigilance and scheduling flexibility on part of pilots. Eventually, low pressure becomes dominant, the sea breezes stop, the southerly wind and rainy winter begins again (B). Eventually, late spring and summer brings local heating and thermal development to our inland sites, till the late summer doldrums begin with northeasterly winds and low inversions.

During the annual cycle, there is a trade-off between consistency and mediocre flying conditions and variability and great flying conditions. Thus, the time of year has an impact on the vigilance required to catch a flying opportunity since times of great variability also brings extremes. Late Spring and Fall are especially good times to fly in Oregon.

Seasonality often requires we fly different sites or change the way we fly sites in Oregon. The Oregon Site Guide offers tips on how to fly particular sites.

Local Scale Weather

Much of the Oregon weather that glider pilots are concerned with is local. It is formed from local heating or wind obstructions not regional pressure differences as indicated in the regional isobar maps. (In actuality, local weather is caused by pressure differences too – just ones we cannot map) Remember, our “weather” is the result of all the fractal scales. Direct heating and cooling of the local terrain creates rising and descending air as well as topography affecting its flow. The following local weather phenomena affect regional patterns.

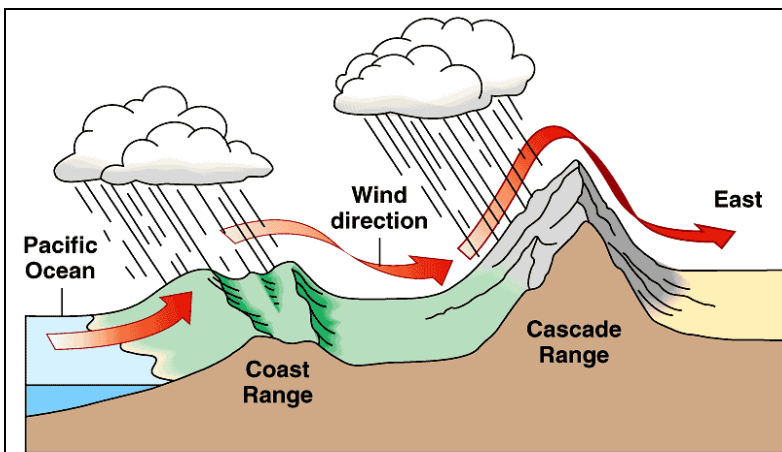


Air currents effect on local air circulation.

Graphic from Aviation Weather NASA

The Oregon Micro-Climates

Oregon’s mountain ranges have a dramatic effect on regional climate. This creates five distinct flying regions. The following is, in part, excerpted from the Climate of Douglas, Benton and County.



As the air descends on the lee side, the air is drier and allows the formation of the eastern deserts. The Willamette Valley gets less rain than on the coast but Eastern Oregon is even drier. This creates five distinct flying climates in Oregon - The Coast, the Coast Range, the Valley, the Southwest and the High Deserts. Notice the rising cloud levels? We can fly much higher in Eastern Oregon.

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The Coast - the coastal zone is characterized by wet winters, relatively dry summers, and mild temperatures throughout the year. Coastal terrain features is characterized by a coastal plain (extending from less than a mile to a few tens of miles in width) and numerous coastal valleys. Extremely high or low temperatures are rare, and the annual temperature range is lower than any other Oregon climate zone. Temperatures of 90 deg F or above occur, on the average, less than once per year, and freezing temperatures are infrequent. Occasional strong winds strike the Oregon Coast, usually in advance of winter storms. Wind speeds can exceed hurricane force, and in rare cases have caused significant damage to structures. Skies are likely to be cloudy during winter, and only partly cloudy during summer.

At Astoria, average winter cloud cover is over 80 percent, dropping only to about 65 percent in summer. Summer cloud cover is due mostly to fog and low clouds due to humid marine and land air interacting with cold sea surface water. As a result of the persistent cloudiness, total solar radiation is lower here than in any other part of the state.

Coastal flying is characterized by smoother, consistent winds that are largely affected by dunes, cliffs and capes. Using ridge-lift updrafts is the primary method of soaring. Since the best wind direction has westerly component (the coast runs north-south), the transition between seasons often provides the best opportunity for flying. These smoother winds are great for teaching beginners and novices how to fly and soar since the air is so consistent. We have six major hang gliding sites along the coast that provide this escalating challenges and consistency.

The Coast Range - The Coast Range, whose peaks range from 2,000 to 5,500 feet above sea level and extend down the full length of the state. The temperature extremes are similar to the near ocean coastal plains but local heating and wind protected valleys create moderate thermals and channeling of sea breezes. The Coast Range is closely associated with the coast and often advanced pilots will transition from coastal flying to coastal mountain range flying.

One site, **Prairie Mountain**, south of Alsea, provides very consistent early summer thermal flying but it is strongly affected of sea breezes in the late afternoon. **Sollie and Kilches**, east of Tillamook; **Andersen's**, north of Pacific City and **Sea Lion Caves** north of Florence all start out as coastal flying but can end up as coastal range flying.

The Southwest - The southwestern interior of Oregon is one of the more rugged parts of the state. Deeply indented river valleys separate mountains and ridges, with most of the rivers flowing westward towards the Pacific Ocean. Although much of the area lies in somewhat of a rain shadow, sheltered from the Pacific by the Coast Range to the west, many of the higher elevation sites receive abundant precipitation with some locations receiving in excess of 120 inches per year.

Due to the ruggedness of the terrain, much of this area remains sparsely settled. The only major urban areas lie in the broader valley areas, particularly the Rogue and Umpqua valleys. Ashland, Medford, and Grants Pass are the major cities in the Rogue valley, while Roseburg is the primary urban area in the Umpqua valley. Due to its separation from the coast, the southwest has greater temperature extremes than the remainder of western Oregon. During summer, it is generally the warmest part of the state. Medford, for example, averages about 55 days per year with maximum temperatures of 90 deg F or above; in fact, the average daily maximum for July is above 90 deg F. Winter temperatures can be quite cold.

Cloud cover is greatest during the winter months, averaging more than 80 percent of total potential cloud cover during December and January. Mid-latitude storms generally produce extensive middle and high clouds, while fair weather periods between storms often produce extensive valley fog, sometimes lasting for many days. Summers, however, are mostly cloud free, averaging only about 20 percent mean sky cover.

Woodrat Mountain, west of Jacksonville, provides some of the most consistent spring, summer, and fall flying in the state. Thermals tend to be stronger and less affected by prevailing winds since temperature extremes and lapse rates are greater. The sea breeze can affect late afternoon flying at Woodrat.

The Willamette Valley – The climate of the Valley is relatively mild throughout the year, characterized by cool, wet winters and warm, dry summers. The climatic conditions closely resemble the Mediterranean climates, which occur in California, although Oregon's winters are somewhat wetter and cooler. Growing seasons in the Willamette Valley are long, and moisture is abundant during most of the year (although summer irrigation is common).

Like the remainder of western Oregon, the Valley has a predominant winter rainfall climate. Typical distribution of precipitation includes about 50 percent of the annual total from December through February, lesser amounts in the spring and fall, and very little during summer. Rainfall tends to vary inversely with temperatures -- the cooler months are the wettest, the warm summer months the driest

The predominant wind direction is north in the summer and south in the winter with westerly transitions between the seasons. Since the cascades are on the east, Northeasterly wind tends to create turbulent conditions in the valley. Since northeasterly winds tend to be associated with high pressure and temperatures, inversions often develop in the late summer. This is July and August “dog days” of hang gliding.

Relative humidity is highest during early morning hours, and is generally 80-100 percent throughout the year. Humidity is generally lowest during the afternoon, ranging from 70-80 percent during January to 30-50 percent during summer. This creates morning low fog or stratus that often burns off in the afternoon. Annual pan evaporation is about 35 inches, mostly occurring during the period April - October.

Winters are likely to be cloudy. Average cloud cover during the coldest months exceeds 80 percent, with an average of about 26 cloudy days in January (in addition to 3 partly cloudy and 2 clear days). During summer, however, sunshine is much more abundant, with average cloud cover less than 40 percent; more than half of the days in July are clear.

The **Coburg Hills**, east of Coburg and Eugene; **Petersen's Butte**, and numerous ideal training hills allow for year-long flying, but requires spontaneity to get the right day. Ridge lift, thermal flying or a combination of both are characteristic of flying the Valley. Thermals tend to be moderate but early summer can create some wire twangers. The sea breeze often develops in the late afternoon in the summer but rarely extends past interstate 5.

The Cascades - The Cascade Mountains, the dominant terrain feature in Oregon, encompass the entire length of the state from the California border to Washington. With average elevations in excess of 4,000 feet, the Cascades are crowned with a number of very high peaks. Mount Hood, near the Washington border, exceeds 11,000 feet, while Mt. Jefferson and the Three Sisters exceed 10,000 feet. Mt. McLoughlin near Medford is approximately 9,500 feet. The Cascades are a higher and more imposing topographic feature in the northern part of Oregon, however. Average elevations and the number of tall peaks (over 9,000 feet) are higher north of about 43.5 deg N latitude. The region extending northward from this latitude to the Columbia River and encompassing high elevations west of the Cascade crest is the fourth of nine Oregon climatic zones.

The northern Cascades exert a profound effect on Oregon climate and weather. Mid-latitude storms approaching from the west are forced to rise as they encounter the Cascades, resulting in large amounts of orographic (terrain-induced) precipitation on the western slopes. So effective are the Cascades in removing moisture from the Pacific air masses, however, that most of Oregon east of the Cascades lies in a "rain shadow," resulting in large areas with annual precipitation less than 12 inches.

Detroit Lake, near Detroit, provides Barker launch, a west facing site and Hall's Ridge, an east facing site. Barker is primarily a thermal site. Halls is best flown in the morning when catabatic winds channeled from adjacent valleys flow up its face. This site is only flown in September, when water levels are drawn down to provide landing zones on the shores of Detroit Lake.

Eastern Oregon - Oregon's High and Low Desert, a region bordered by the Cascades on the west and several minor mountain ranges on the south and east, comprises much of Eastern Oregon. Due to generally high elevations, the High Desert has cool temperatures and receives a significant amount of snow. Its distance from

the coast, coupled with its location downwind of the Cascades, causes its annual precipitation to be lower than in the mountainous areas surrounding it. The combination of high elevation and distance from the coast can produce cold temperatures in any month of the year.

The Cascade crest, running north-south at a longitude of about 122deg W, is lower in elevation in the High Plateau than in most parts of Oregon. Only one peak, Mt. Thielsen, exceeds 9,000 feet. As a result, the 'rain shadow' effect produced by the mountains is less dramatic in this zone than in areas to the north. Another notable difference between the High Desert and the surrounding zones is its average elevation east of the Cascades. Whereas the places east of the northern and central Oregon Cascade peaks are typically 2,000 - 4,000 feet above sea level, the lower elevations of the High Desert average about 5,500 feet.

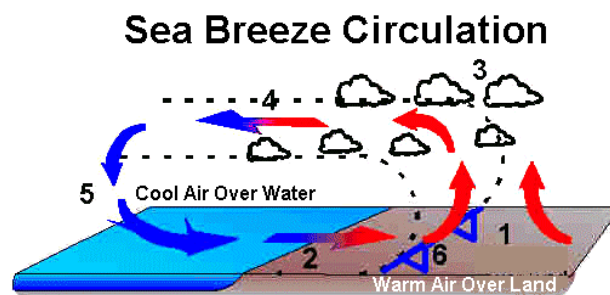
As air moves from west to east over the Cascades into Eastern Oregon, it begins to descend; the greater the descent, the drier the air becomes. While air parcels reaching Bend to the north have descended into the Low Desert about 4,000 feet from the crest and are usually quite dry, similar air parcels moving into the High Desert drop only about 2,000 feet. This difference is reflected in the average annual precipitation total for these two areas. Bend receives only about 12 inches per year, while points in the High Plateau receive more than 20 inches.

Pine Mountain, southeast of Bend, in the Low Desert, provides a Cross Country starting point for many advanced pilots. Since the ground cools off quickly in the evening, but the day heats up rapidly, lapse rates can be high and thermals powerful. **Lakeview**, a series of 5 sites in and around the city in the south central high desert, also provides cross country flying in many directions but also provide glass off opportunities for novices and intermediates.

The Local Winds

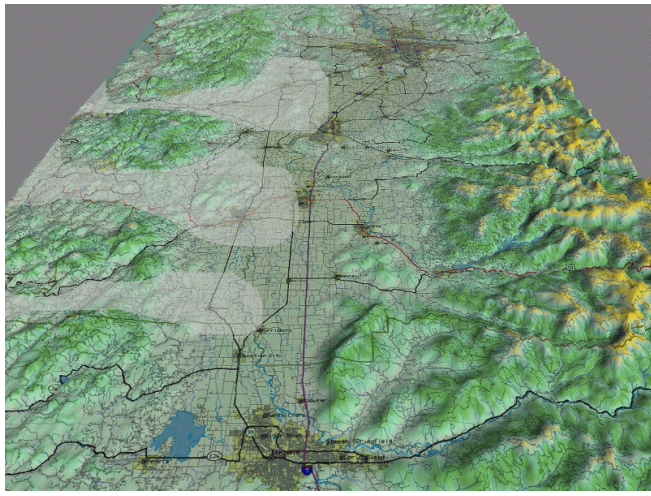
The Sea Breeze

One of the largest scale local weather effects is the sea breeze that affects the Coast, the Willamette valley and the Southwest. During the summer months, the location of a regional scale high pressure in the Pacific Ocean is the cause of the prevailing north wind on the Oregon Coast. However, intense heating of the inland Willamette Valley creates a more local sea breeze that strongly affects the regional pattern. This provides a westerly component that steers the north coastal winds northwest and makes for easier soaring. How effectively the sun heats the surface of the valley will affect the wind direction on the coast. It's this superposition of scales and estimate of the relative intensity or dominance of each that provides you the big picture.



Graphic from Weather Phenomenon and Elements

The sea breeze is an example of a relatively large local-scale weather event. It especially becomes apparent at the coast and at more inland coast range mountain sites like **Prairie Mountain** near Alsea or **Sollie Smith** east of Tillamook in the middle of Summer.

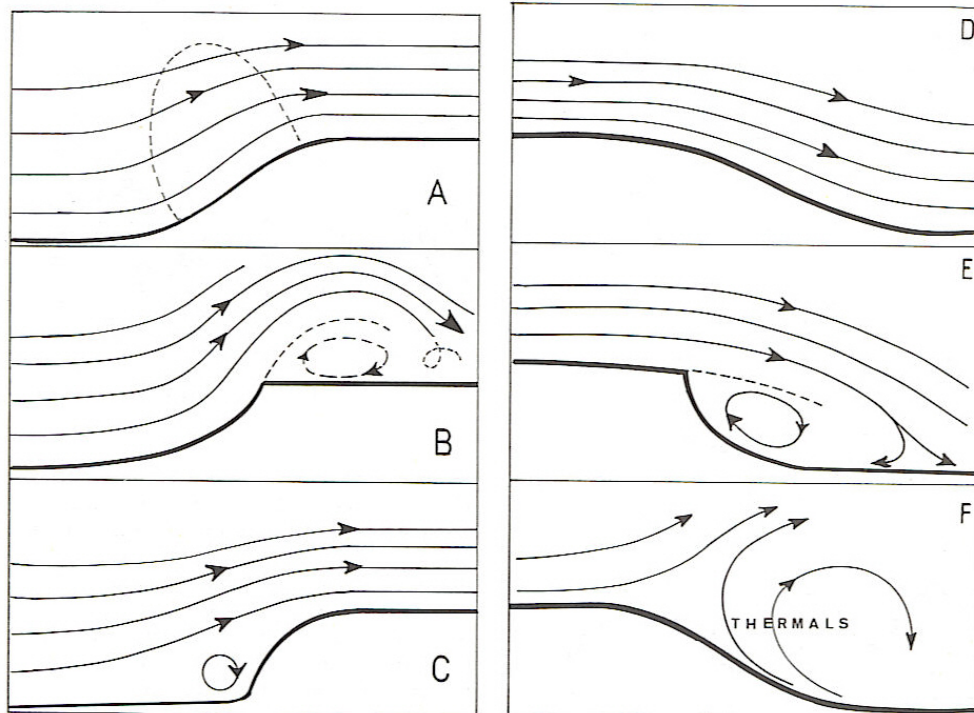


The sea breeze takes advantage of low passes as channels in the coast range near Eugene, Corvallis, Salem and Portland. During particularly strong sea breezes it can go inland as far as I-5 and flow over the Coburg Hills near Eugene making the **Southwest Bowl** soarable. But, this is very rare. It usually diminishes before it reaches Interstate 5.

Often, this sea breeze will add a westerly component to prevailing northerly winds, especially on the coast. Depending on how much effective Valley warming there is it can mean the difference between soaring Cape Kiwanda or just training on the lower slopes. However, are smaller scale local effects that are superimposed on regional patterns. Mountains have many effects on the weather because of differential heating of slopes, forcing of air around topography, and the release of moisture from the air.

Using the Flow of Wind over Topography - Ridge Lift and Sink

Wind flowing over hills, mountains and ridges is a major determinant of how and why we fly. The rising air over these obstructions provides the lift needed to soar and interacts with thermals and changing air temperature to cause to all sorts of weather effects and flying conditions. On a low ridge (A) the wind is deflected upwards and as long as the slope doesn't change abruptly (B and C) the wind flow will be laminar. All these have a soarable envelope (dashed line in A) that gets more effective (needing less wind) on steeper slopes and direction the slope is facing.



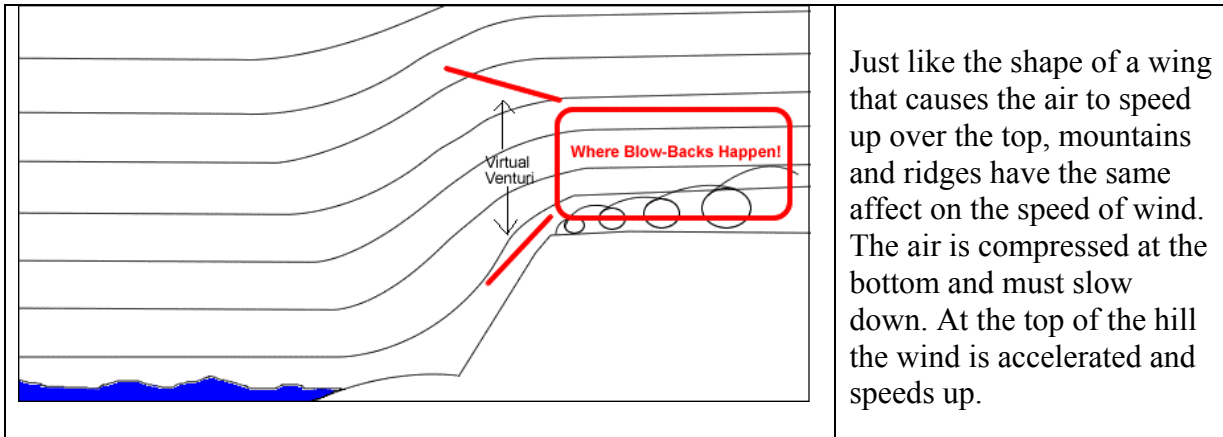
Graphic from Meteorology and Flight 2nd ed

However, abrupt changes in slope or trends of slopes also cause **rotors** (B, C & E). These are eddies of air that can cause gliders to go wildly out of control or at least cause trouble. Thus, visualizing wind flow around different shaped terrain surfaces and objects is an essential skill for pilots to have. Safe pilots will always

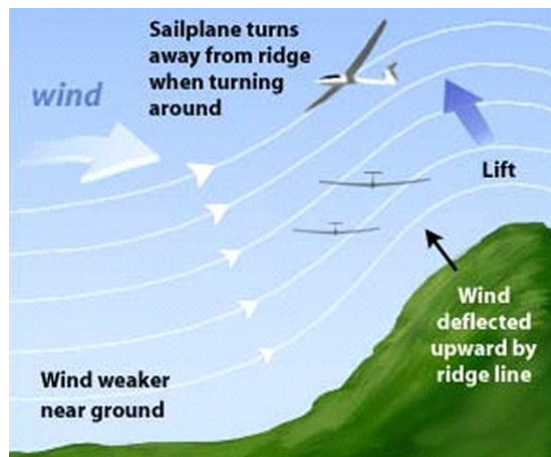
choose the smoother (more laminar) conditions in which to launch, fly and land - even if it requires inconvenience.

Compression, Expansion and Blocking of Wind – Venturi Effect

You may have noticed the wind speed be noticeably decreased at the bottom of the training hill versus the top of the training hill. That is because the wind is blocked by the hill near the bottom and is unrestricted near the top. At the top, the increase in speed can be great. There often is a gradual increase in wind from the bottom to the top of training hills. Simply pick your level for your current skills. Even advanced soaring uses this effect. If the wind is too strong over the peak, then staying out in front and low of the ridge can still allow comfortable soaring.

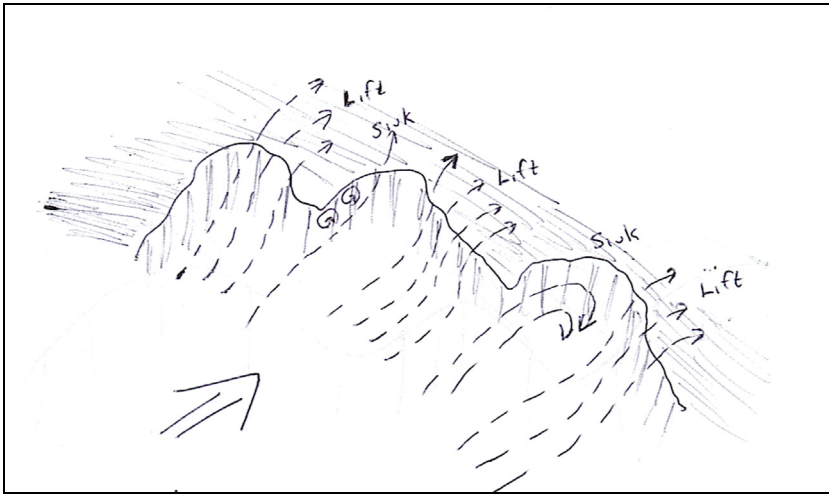


The greatest acceleration and turbulence happens low and on top of ridge lines. Care must be taken that your glider's top speed and maneuverability is not overwhelmed. Stay low and in front if in doubt.



Graphic from Soaring Society of America

The area of most lift is at 45 degree angle from the upper portion of the slope. This lift band increases and decreases in elevation with the wind speed. But it also diminishes with an increasing oblique angle of the wind direction. At 90 degrees (right or left cross wind) the lift goes to zero.

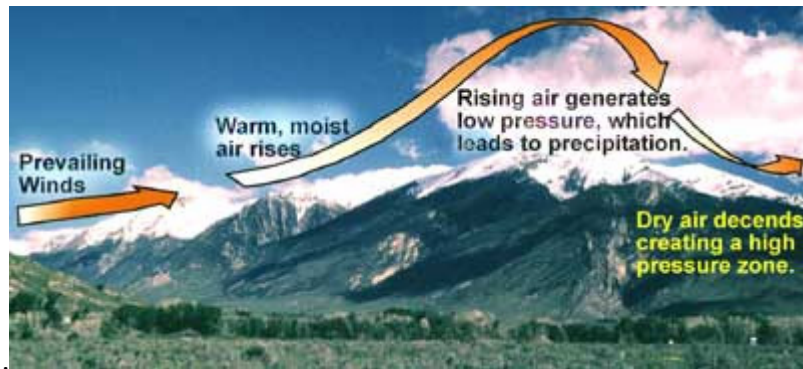


Visualizing the airflow around the changing trend of ridge lines will optimize a flight and also keep a pilot safe. We do not want to fly into areas of rotors or sink. We also want to remain vigilant of shifts in wind direction that will affect the areas of lift and sink.

Weather Effects of Air Flow Over Mountains

Since we often want to be in the mountains with wind flowing over them, we need to know some of the secondary effects of this flow.

The flow of wind over larger mountains include the cooling and warming of the air masses as it rises and descends over the mountains. In the first case, air rising expands so it causes lower pressure. Since it is at higher and colder the dew point is reached causing water contained in the air to condense and form clouds. Depending on how much water is entrained in the air and how high the mountains are, the clouds can drop the water as rain or snow. But sometimes only clouds are generated.



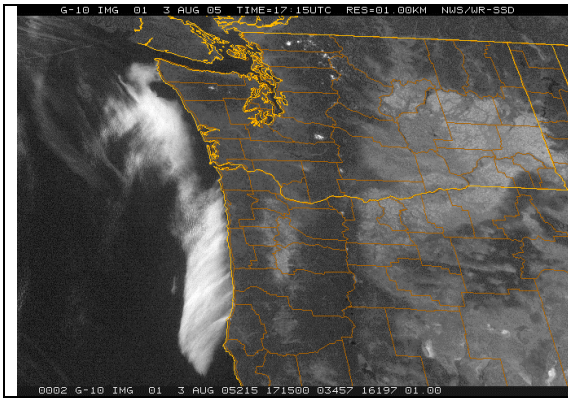
The cascades form an effective block of moisture to Eastern Oregon. But, the Coast Range is less effective block for the Willamette Valley because of its' lower elevations. Nevertheless, the coast gets more rain than the Willamette Valley.



Clouds can spontaneously form during a flight as you fly at the condensation level. It is very important to fly the lift and terrain so that you can “escape” from being caught in a cloud during these times of spontaneous cloud formation. Without visual reference to the terrain, there is no way a pilot can tell if they are upside down or right side up or even what side of the mountain you are on.

Descending Air and Formation of low stratus and fog

Although descending air gets drier on descent, sometimes the warming air is able to evaporate more water, especially if there is a moist rainforest underneath. In this case, warm humid air can create intense summer fog on the coast as it is cooled by the cold ocean.

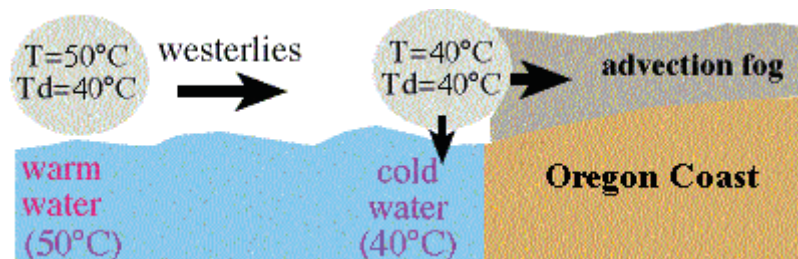


This effect occurs when summer northeasterly winds flow from inland over the coast range onto the cool ocean surface. Since the air descends and warms as it goes, it evaporates more water and becomes more humid. This humid inland air is cooled by near shore ocean water to form fog and low stratus clouds.

However airflow from the ocean can cause the low stratus and fog as well.

The Late Spring and Summer Marine Push (Following excerpt from "What is the marine push?")

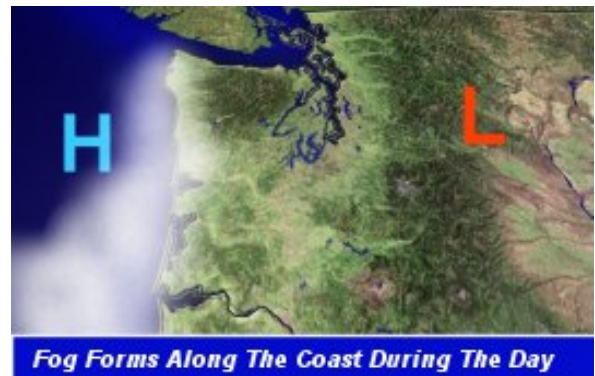
Marine air masses pushes are the summertime occurrences that bring our steady diet of morning fog and afternoon sun. It also contributes to our "natural air conditioning".



On most days in the summertime, there is higher pressure that sits offshore from Western Oregon and lower pressure inland. Most of the lower pressure is from the heat in Eastern Oregon and, the daytime warming of Western Oregon. Meanwhile, fog and low clouds develop along the coast, as the warm air from the sun tends to condense into fog over the much-cooler Pacific Ocean.



Higher Pressure Builds Over The Ocean
Lower Pressure is Situated Inland



Fog Forms Along The Coast During The Day

As the ground heats, the hot air rises. That creates a little bit of a "vacuum", if you will, that will draw air in from the outside to replace it.

That air will usually come from the higher pressure offshore. Thus, at nighttime, we'll get a push of air from the ocean through the low passes in the Coast Range.



Many times the marine push will bring in fog or low stratus along with the cooler temperatures. When this happens, we'll usually begin the day under low clouds and fog, and then it'll slowly burn away, leaving mostly sunny skies in its wake.

The strength of the marine push can vary greatly, to where we can be stuck in the fog for most of the day with temps on the low 60s, to just a light patchy fog (or even no fog at all) and just a slightly cooling effect, and temps in the upper 70s/low 80s. It all depends on the relative strength of the high and low pressure, and the amount of low clouds along the coast and strength of the sea breeze.

If the low stratus burns off by 12:00 noon, and the day's lapse rate is large enough, there could be some great flying for the afternoon. Knowing that this will occur and **believing it** by heading to the thermal site before the clouds burn away is a way to get some sure air-time in the early summer.

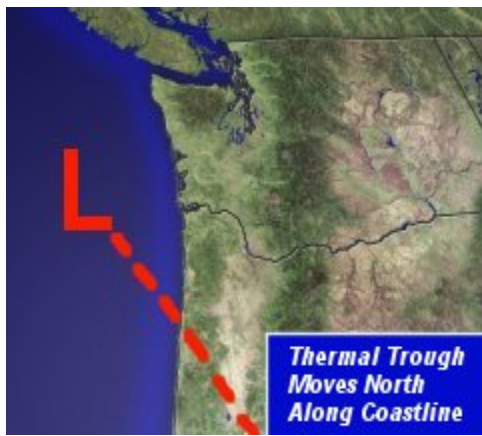
The Summer Heat Wave and Coastal Fog

The thermal trough is responsible for almost all of our extreme heat waves in the summertime. This heat wave often brings inversions in the valley (a layer in the atmosphere that gets warmer with height) that stops thermals in their tracks. On the coast, erratic fog and low stratus can completely sabotage a flying day. The cause of this is due to a low pressure trough coming through the region. Most of the time, we associate low pressure with stormy, rainy weather. But intense heat can also cause low pressure as the air rises faster than it can be replaced.

In the hot desert, you have a lot of warm air rising into the upper atmosphere. That creates lower pressure near the ground as you now have less air around.

This is a near-daily occurrence in the summer in Eastern Oregon and the Desert Southwest and California. However, if strong high pressure moves south out of Canada and into the Rocky Mountain states, that can actually push the thermal trough north into the Pacific Northwest.

At this point, the placement of the trough is key to the temperatures around the area. In some sense, it might be best to think of the trough as a valley, and air will want to pour into the valley to fill it.



A few times a year, the trough will actually come north either along the Pacific Coastline or even out over the ocean. When that happens and the trough is to our west, you have air now rushing from the east out toward the offshore trough. That offshore flow will bring us very warm temperatures -- probably some of the warmest of the season.

The trough can stay offshore for a few days, bring an extended heat wave to the area. In these cases the inland air can compete with sea breezes, catabatic flow and nearby highs to cause erratic fog development.

These local effects often interplay with regional fog development on the coast. Catabatic Coast Range winds (denser from night-time cooling but still warmer than the ocean) descend offshore into nearby coastal waters causing near shore and offshore fog during the evening. In the morning, when the valley heats up and the sea breeze and marine push become dominant, an offshore fog bank develops but the coast clears up.

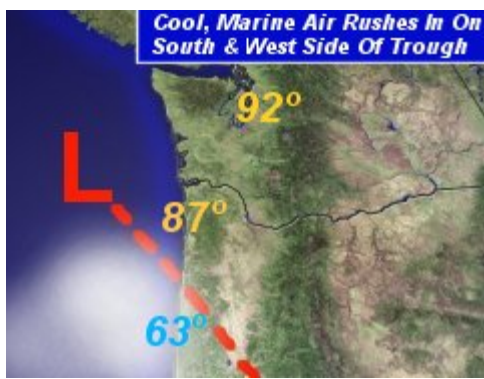
If the marine trough winds become dominant, relatively humid inland air descends and mixes along the coast especially on the windward northern sides of capes and peninsulas. This patchy fog can at times be very intense as the northeasterly winds blow strong. But they can disappear as the wind shifts westerly and the "fuel" for the fog is cut off. You can always find relief on the southern side of large capes. Two big factors in this fog development is the presence of higher humidity marine or inland air flowing from the sea or land and cold sea surface temperatures.

But eventually, the predominant westerly flow will win the battle, pushing the trough east into Eastern Washington and beyond.

As the trough pushes east of your location, the winds will shift from northeast to northwest, bring a rush of cooler, ocean air into the region, most likely triggering a more dominant marine push and bringing an abrupt end to the heat spell. It's not unusual to have one day where it is 93 degrees outside, have the trough move east, and then have the next day be about 67 degrees under a heavy fog.

Usually, on the visible satellite, you can see fog moving north from the California Coast into Oregon as the trough moves north and east of those areas, thus bringing the cool ocean breeze behind it.

You can also keep tabs on the Oregon and Washington Coast cities' current temperature. As the trough passes each city, the temperature will take a huge drop (usually into the upper 50s or mid 60s), the wind will shift to a west/southwest direction, and the fog will roll in. The start of trend is usually obvious with drop of temperature in Eugene with marine push flow coming through the low pass west of Eugene.

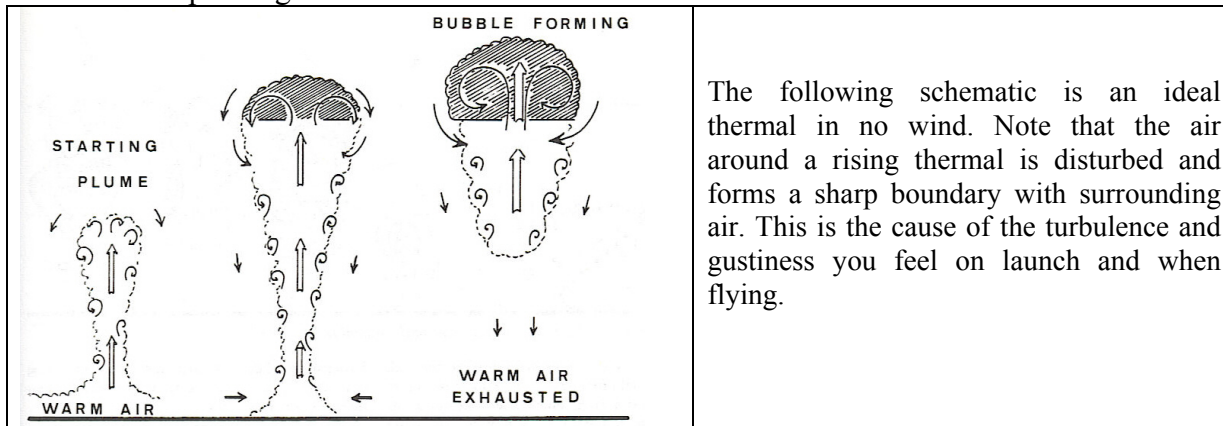


As it comes up the Oregon Coast, that's a 1 day warning that the heat wave is coming to an end for the Washington Coast, and a 2-2.5 day warning that the end of the heat wave is coming to Seattle.

Thermals

Once you have graduated from flying smoother winds and are confident of control and you have soared in smoother winds – than you are ready to experience increasing localized lift. By necessity this means more turbulent and bouncy air. Thermal flying is where the art of flying really takes off because you no longer so tied to local topography.

Here is a simple diagram of an ideal thermal.

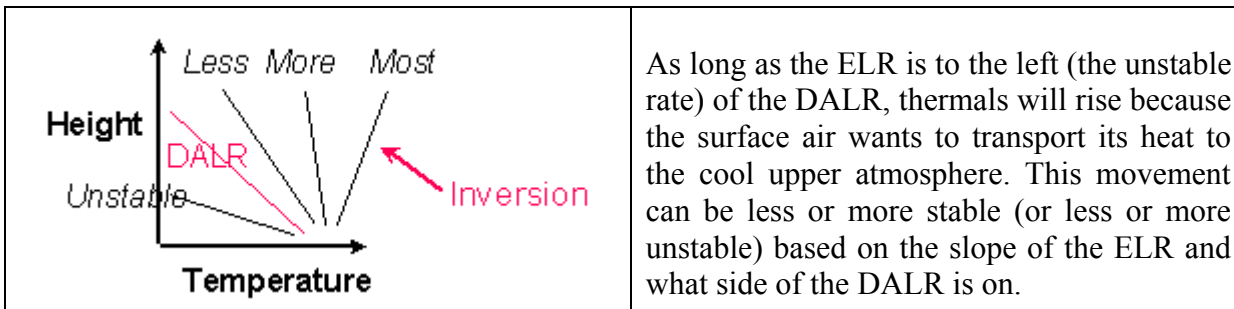


Graphic from Meteorology and Flight 2nd ed

Thermals have a regular cycle of warming of air at the surface, detachment from the surface, and exhaustion of the warm air. The cycle then starts again on a frequency that depends on the efficiency of the heating at the surface. Thus, you can “time” the thermal based on the gusts and lulls that you feel at launch or when flying around the local “house thermal”

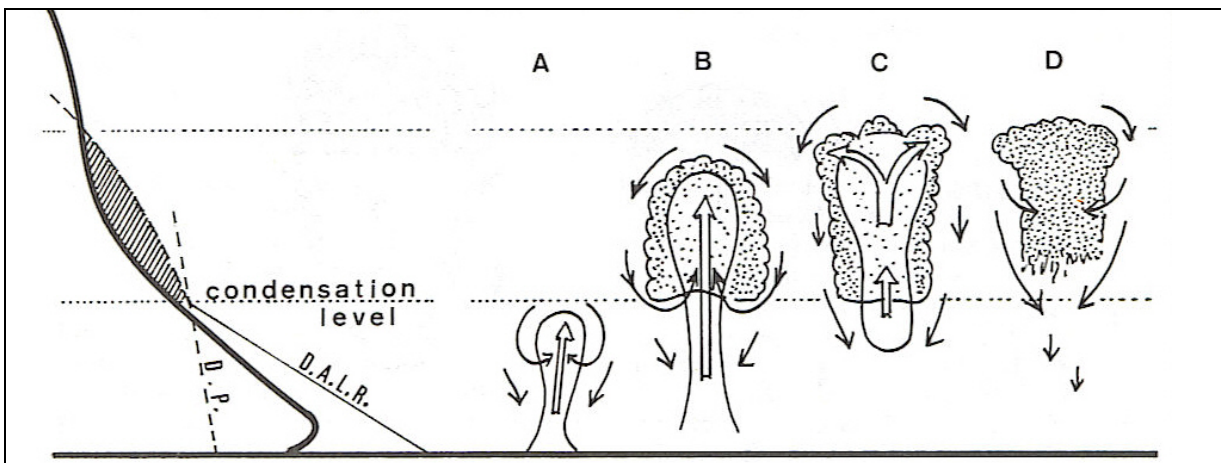
As the thermal rises it creates sinking air all around it. Thus, getting caught in thermally air will have you rising and falling dramatically at times, unless you know how to stay centered in the thermal. “Wet” thermals often end up as thick cumulus clouds, so if you do end up staying in a thermal it is quite possible to be “sucked up” into the cloud. Most of the time, novices find more sink than lift and find themselves on the ground, quite frustrated that everyone else is soaring.

The speed and strength at which it rises depends on the **Environmental Lapse Rate (ELR)** which is simply the temperature difference between the surface and some height in the atmosphere. The thermal condenses into clouds at the point of the atmosphere at which air cools to the dew point.



As beginning mountain pilots, it is important to choose that part of the day in which heating is only beginning or waning. This is especially true on an unstable day, when there is big difference in surface and upper elevation temperatures and we expect lots of ground heating. By choosing the early part of the day, the thermals have not had time to develop and the air will be much less turbulent. Similarly, the end of the day, as the sun lowers, heating is lessened considerably and the thermals begin to wane. It is very difficult to learn landing approach skills when your control skills are being tested by mother nature!

This is so important we need to be able to recognize a stable and unstable day more definitively.

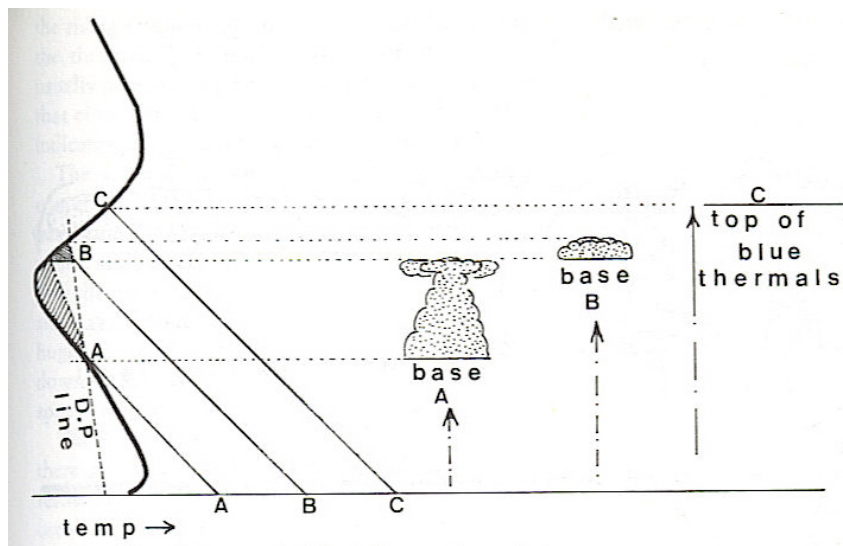


Graphic from Meteorology and Flight 2nd ed

40 45 50 60 70 80 90 C X

Here is a diagram of the thermal process. The X axis is increasing temperature. The Y axis is elevation. Note, near the surface, as air warms up near the ground, the ELR (the thick line) gets warmer initially. This is the warm layer of air on the ground that forms the thermal. A steeply left leaning atmospheric lapse rate means more instability - the stronger the thermal will be. Where the dew point D.P., meets the DALR and the ELR, the cloud forms and the thermal slows down considerably. Note the changing slope in the ELR above the condensation level? The top of the rising cloud is where the temperature decrease with altitude weakens and stops the cloud from rising further.

Sometimes the D.P. will lean left as well, never intersecting the DALR and ELR or the amount of initial heating is such (C) that thermal rises to the inversion without ever reaching cooling to the dew point. This is a "blue thermal" with no cloud development. These thermals have to be flown solely by "feel" since there are no apparent signs of their presence.



Graphic from Meteorology and Flight 2nd ed

Choosing to fly in stable conditions is important in the early stages of flying in the mountains because turbulence is less likely to confuse your newly learned control skills. Later, when control skills become unconsciously competent, we may fly in exceedingly unstable conditions (more left leaning ELRs) till we are able to fly in moderately turbulent air. As a beginning novice hang glider pilot you must make sure to only fly during the part of the day that has relatively little thermal activity or which have been subdued by cloud cover.

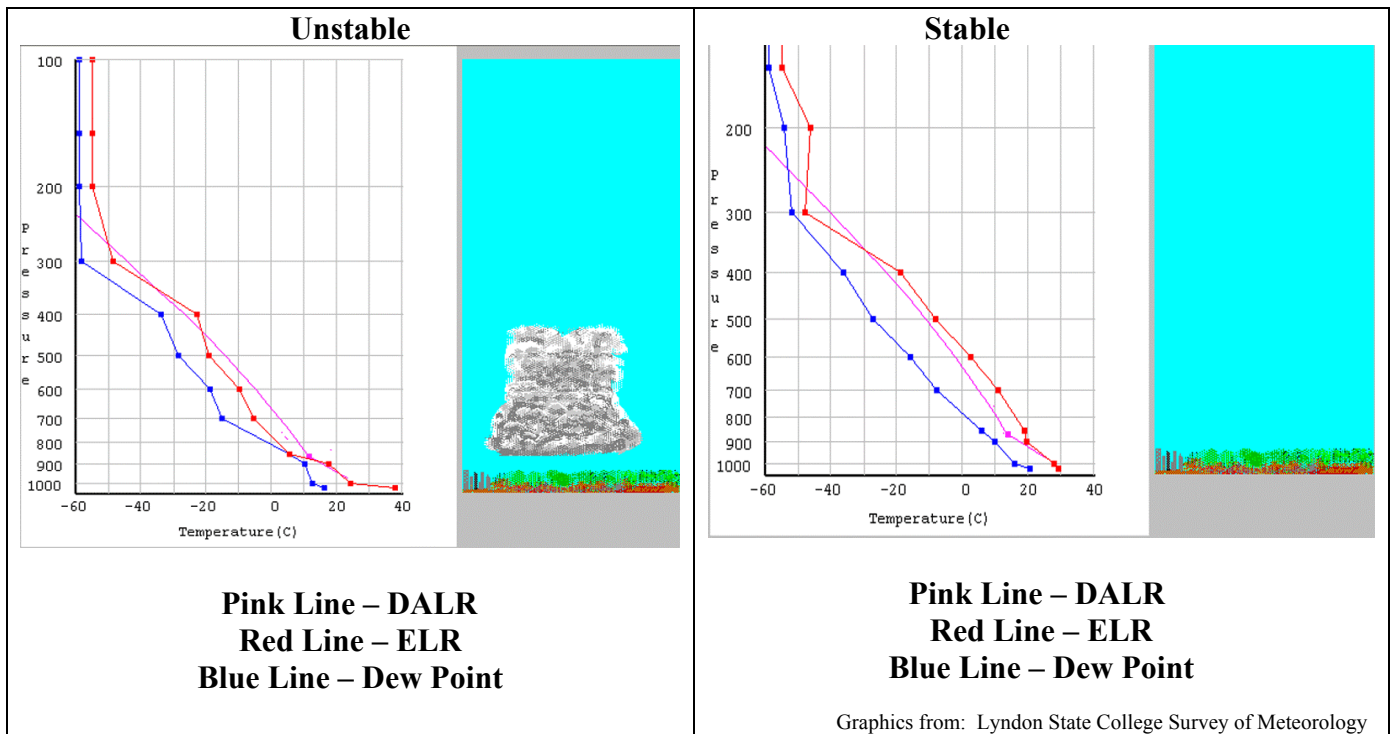
Thermal and Cloud Evolution

In the real world, the first thing that you'll notice is a dramatic temperature difference between the valleys and mountain tops. The sun will be heating the valley floor efficiently through thin clouds if they are present. The second thing could be some early development of cumulus clouds that quickly develop, grow and coalesce or just dissipate and redevelop. Along with this, will be cycles of wind gusts that come into launch that get steadily stronger, more persistent and frequent. In the landing zone, you will see increasingly switchy wind directions and strengths as thermals draw in air from all directions.

	<p>The life span of cumulus clouds are synchronized with the formation and dissipation of thermals. Light wisps form and expand quickly at first as the thermal reaches the condensation level. The cloud billows and becomes fully developed with sharp edges. It then turns ragged and dissipates as the thermal source is depleted of heat.</p>
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Charting and Forecasting Thermals

Forecast tools include **soundings**. They are the current day's environmental lapse rate temperature profile and dew point temperature with altitude. On any day in which significant heating of the surface will occur and the appropriate DALR line is to the right of the ELR, thermals will rise to that intersection. **The increasing slope to the left of the ELR indicates how strong the thermal may be and whether you should go try to fly!** The DP intersection level can also tell you if clouds will form too low for safe flying or if you will experience a "blue thermal" day.



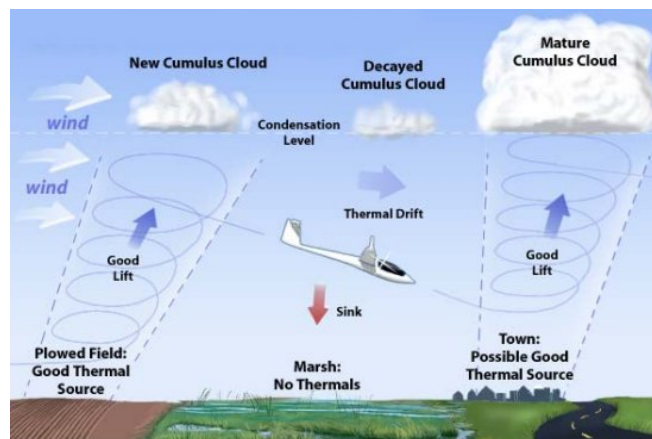
In the example to the left, the ELR is to the right of the DALR and leans strongly to the right. The dew point intersects the ELR at 900 mb where cloud base forms. The thermals are strong. On the right, the ELR stays to the right of the DALR, the lean is not great and the dew point never intersects the ELR. The thermals are weak and no clouds form.

Thermal Height Rule of Thumb

Multiply the difference in highest forecast surface air temperature and the dew point by 400 to find the height of the cumulus base in feet. So, if on a sounding the surface DALR starts at 29 C and the surface dew point starts at 19 C there will be a 10 degree difference. Multiply this by 400 and you get a cloud base of 4000 feet. This only works as the air continually warms to its highest temperature and when there are no significant breezes to mix the air. In this latter case, it is accurate to say that cloud base will be no lower than 4000 feet.

Using Thermals

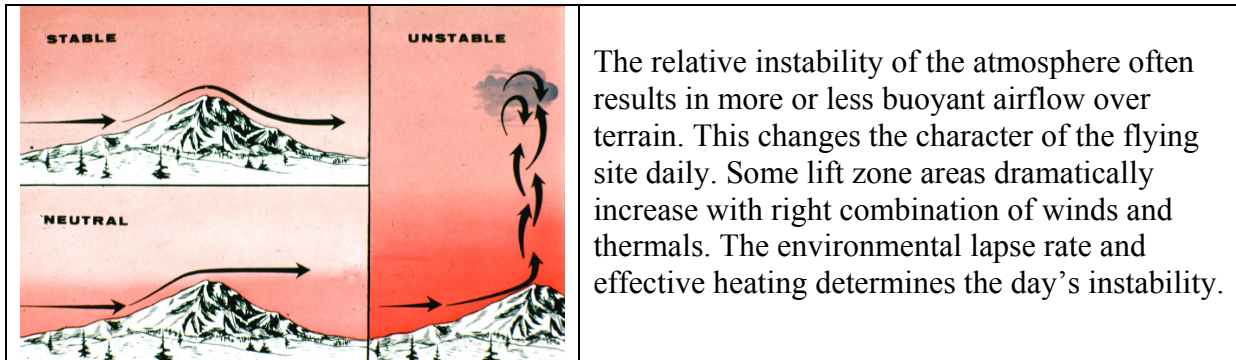
Thermals drift with the wind - just like smoke plumes - and they form and dissipate spontaneously. The use of variometers, instruments that detect rising air in feet per second, are often needed to identify the thermal in the air. But, knowing what fields are likely to cause thermals or actually identifying thermals by the clouds that they create can also help. This is the art of hang gliding that takes years to develop to an advanced level.



Graphic from Soaring Society of America

Buoyancy of Winds – Thermals combining with Ridge Lift

Thermals tend to develop in the valley along the lower slopes of mountains facing the sun. These slopes also deflect and direct thermals from the valleys and provide some extra buoyancy to the wind that is moving up and over the mountain.

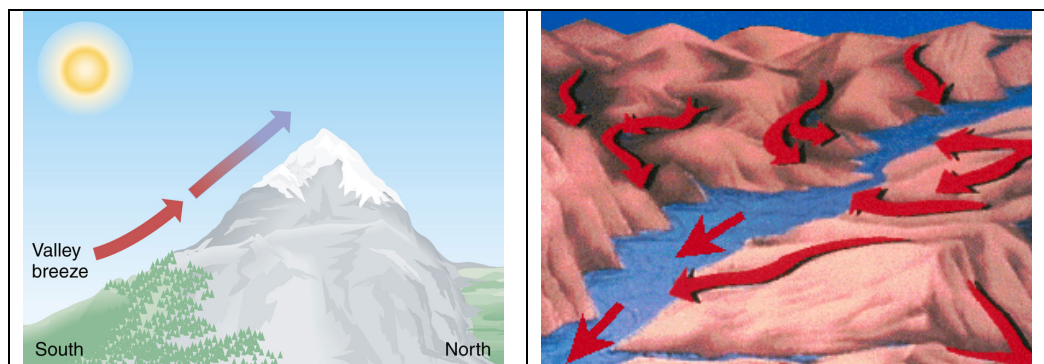


The thermal character of a hang gliding site depends on geography and heating. As the sun's direct rays move, so does the lift and sink. When on launch, these mountain hugging thermals create some interesting launch dynamics. Since they form in cycles of heating and dissipation, the frequency in which they travel up the slope depends on the level of heating during the day. Catching the beginning, middle or end of one these cycles can mean rising to cloud base or just "sledding" or gliding down to the landing zone

Areas that absorb the sun's rays like the coast and valley have subdued thermals as most of the sun is absorbed by water on the surface and green plants. Lift can be measured in ascent rate in feet per minute. Areas in the Willamette Valley, on average, have ascent rates upwards up to 400 - 1000 feet per minute. But, areas in the eastern deserts can have thermal climb rates upward to 2000 feet per minute, with surrounding sink being just as dramatic.

Of course, these are just averages, to give you an idea why some sites are rated for more advanced skill levels. Some sports, like kayaking, have very obvious indicators of the level of challenge – a waterfall class 5 versus a tame stream at class 1. Learning how to recognize flying challenges in the air is more subtle and takes more study and experience. The following are some daily local mountain weather phenomenon you should be able to recognize for safety's sake.

Valley and Mountain Breezes



Valley breezes are simply thermal driven air that ascends the mountain in late morning. In the evening, the tops of mountains cool, the air layer becomes dense and cascades down in a mountain breeze. Often these breezes follow the topography (above) just like water in a network of channels. When you combine these simple effects with topography and differential heating, the complexity of the winds in the mountains can be very interesting. Here is a typical scenario.

Squally and Stormy Weather





We cannot talk about Oregon hang gliding without discussing unsettled and stormy weather. Flying in Western Oregon is a challenge because of its intense variability. However, this variability lies in the moderate zone. We rarely get snowstorms, thunderstorms, or months of hot or cold weather. In fact, when we develop some level of skill we often choose to fly in windows of opportunity between the more moderate events. But, it takes some time and incremental experiences to develop the wisdom to fly these windows safely.

Local Low Pressure Cells, Squalls and Gust Fronts

Squalls are local low pressure cells that dramatically affect wind and rain conditions. Squalls often have showers or virga (rain that evaporates before falling to surface) associated with them. The level instability in these low pressure cells is generally less pronounced than in the eastern deserts or anywhere in the continental US.

Despite that, squalls are always preceded by dramatic increase in wind called a **gust front** and cause the wind to change directions. Flying near smaller squalls and low pressure cells on the Coast, in the Coast Range and in the Valley of the Pacific Northwest is normal - if they are going to bypass the flying site and are small.

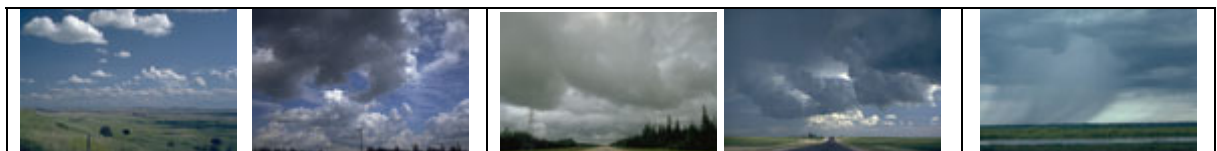
However, squalls headed right towards you will dramatically affect your flight. It takes much experience to know if a squall can be avoided in flight. It is best to land before it draws near.

			
Scattered clouds, great winds and carefree flying	Light (see through) virga in upper left with alert glider pilot flying.	Far off more diffuse but larger squall. Should I land before it gets any closer?	Heavy squall that will be preceded by heavy wind, a change in direction and rain. Land!

Thunderstorm Development

Anywhere where ground heating is greater and moisture is present, you may have the potential of thunderstorm development. Thunderstorms start can start out as fairer weather clouds but the feedback process has greater potential.

The Cascades and Eastern Oregon has a greater potential for cumulo-nimbus and thunderstorm development. The associated lightning and gust fronts can be intense and often create lightning strikes and dust storms in the desert. Here are some typical clouds associated with these thermally unstable conditions. It can often start out as a great day for flying! Watch out for cumulonimbus development and their associated gust fronts.



Developing
Cumulus

More instability

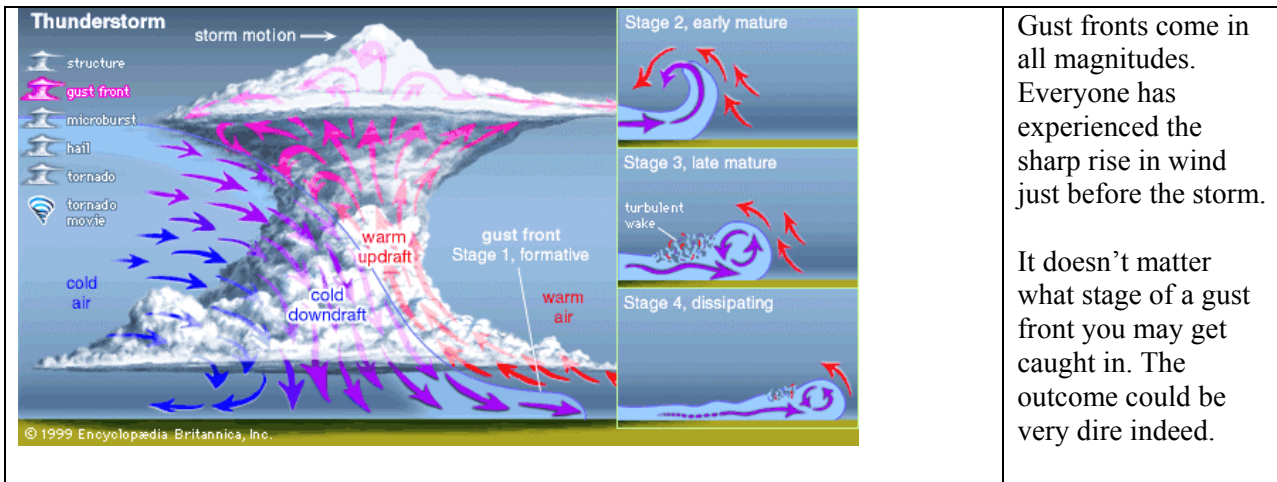
Coalescing
(overdevelopment)

CumuloNimbus

Thunderstorm

The extent of the vertical and horizontal development is determined by the magnitude of vertical winds that have created the cloud. If a cloud is over-developing, it is important to land as soon as possible. Gust fronts

associated with these storms have killed pilots the world over. Here is a graphical description of their dynamics.

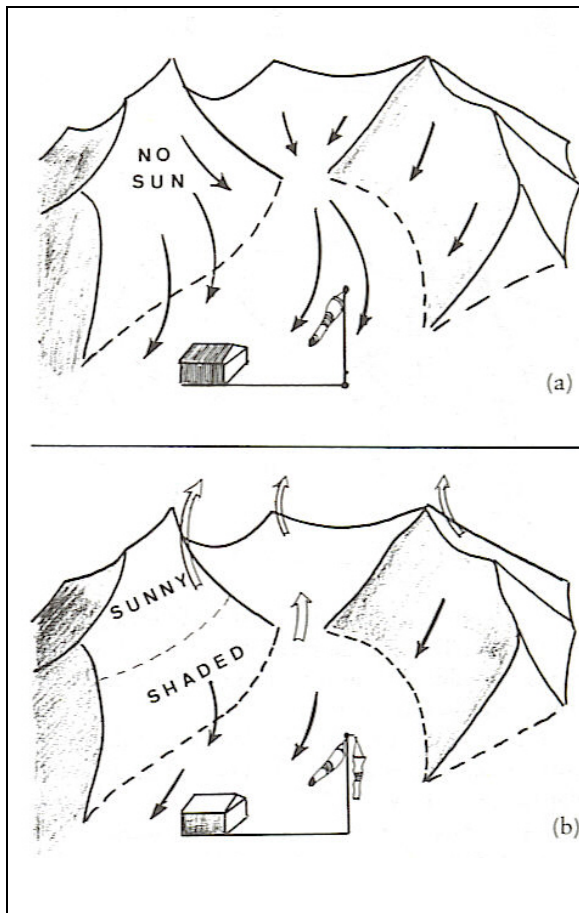


Gust fronts come in all magnitudes. Everyone has experienced the sharp rise in wind just before the storm.

It doesn't matter what stage of a gust front you may get caught in. The outcome could be very dire indeed.

Mountain Weather

The interaction of the changing position of the sun with mountain slopes causes localized heating that creates complex air movements. The daily cycle of these downdrafts and updrafts is predictable so that we can choose the best time to fly. Choosing the wrong time to fly can mean the difference between a harrowing experience or a magical carpet ride.



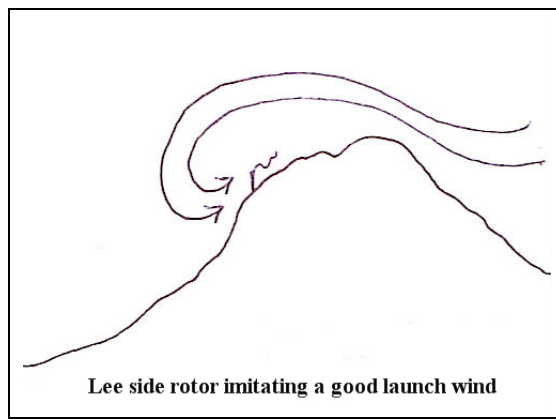
At night time, when the sun has gone below the horizon or even earlier, the slopes of mountain air cool and become denser. This heavier air avalanches down in **catabatic flow**.

Sometimes this wind can develop quickly in the evening. Pilots launching at this time should be alert to the possibility of getting **“flushed”**, e.g. launching and flying in a tailwind all the way to the landing zone.

In the morning, when the low morning sun radiates on the upper slopes, these areas begin to warm and create thermal updrafts. Areas of shade still have sinking air. This may be a good time for novice flights.

Graphic from Meteorology and Flight 2nd ed

When assessing wind conditions in the mountains, it is important to grasp the larger airflow around the mountain. Simply depending on the wind indicator at launch can be deceiving. For instance, if the wind is flowing over the backside of the mountain, you may be experiencing the updraft of the lee-side rotor. Always check the cloud drift and look for wind signs on the other side of the mountain.



But, assuming that you are not being deceived, the continued heating in front of the mountain will create cycles of increasing wind with greater frequency and intensity. By 12:00 noon you will probably be experiencing a greater gust and switchiness factor. The gust factor is the time it takes for the peak wind to repeat itself. The switchiness factor is how fast the wind changes direction. An increase in both requires greater control skill.

<p>(c)</p>	<p>At the peak of heating during the day, when sun has been overhead for a couple hours, around 3:00 - 4:00 pm for most areas, the thermals are at their greatest intensity.</p> <p>The wind speed, gust factor and switchy nature of the winds increase markedly at launch.</p> <p>The landing zone may at times become calm and gusty as the thermals are born, ascend and die with the day's unique frequency.</p>
<p>(d)</p>	<p>Areas of illumination and shade can mean the difference between soaring and landing and cause different wind directions in the landing zone.</p> <p>Finally, when the heating gradually wanes - so that no sudden cool and dense catabatic layer forms - the thermals will gradually diminish and air will be smooth.</p> <p>Graphic from Meteorology and Flight 2nd ed</p>

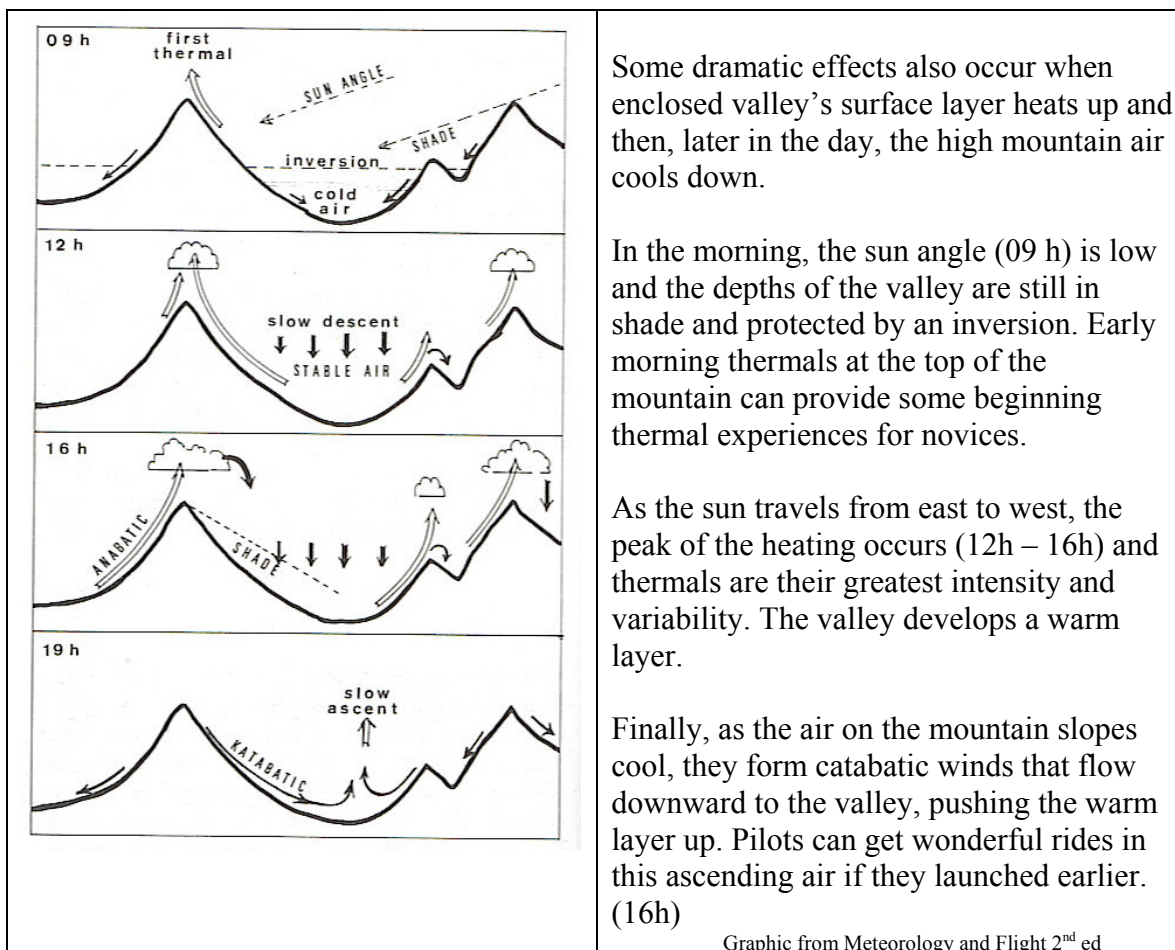
All of our mountain sites exhibit these kinds of cycles and we must have multiple experiences with them to realize what is happening.

Special Conditions – Glass Offs

Some kinds of uplift are so broad and easy to fly in that are termed “**magic air**” or “**glass-offs**”. This can happen in a couple of ways. One way is as described by the flushing phenomenon above. This usually happens at the end of the day, when a cool and dense layer on the mountain rapidly develops. This layer will literally avalanche down the slope to replace the warmer layer on the valley floor - almost like a mini cold front. The climb rates will be moderate but persistent throughout the process of lifting.

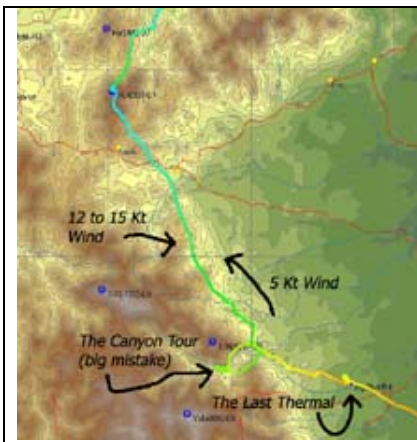
But often, a pilot must pay a price for this free ride. Unless, the process of mixing is complete, a landing pilot will find the interface between these layers. This boundary is often turbulent and shocking to the pilot experiencing it for the first time. However, the layer is often only 50 to 100 feet thick and once the pilot has flown through it, they will experience the smoother flow of the lower layer.

Sometimes, the valley floor begins to release its heat without the assist of a cooler layer replacing it. The valley floor more gradually radiates into the cooling upper layers of the atmosphere. Like a house that has been superheated during the day and the occupants feeling its warmth as the nighttime temperatures decrease, the valley will more subtly and gradually create a buoyant layer and light thermals.



Woodrat Mountain near Jacksonville Oregon has a semi-enclosed landing zone that will allow the experience of a glass off and the subsequent turbulence on landing. Smart pilots wait for the mixing to complete before landing.

Other effects can arise from convergences of air flow from separate directions due to the forcing of the air around terrain. When these effects are found and flown they are often euphoric flights for pilots.



Mountain winds can interact with prevailing winds when meeting at the entrance of valleys, or converge with other valley winds.

This is an area where a side canyon's down slope flow **converges and rises** with the prevailing wind along the front range.

The variations of lift and sink that develop as thermals, geography, the shifting sun and wind and nature of the air interact are countless. That is why hang gliding is so interesting.

Weather and Personal Limits

When learning how to fly in a foot launched program of instruction, the weather complicates all learning. We must learn to choose weather conditions and sites so as not get overwhelmed. It only takes one factor for which a pilot is unprepared to have a major accident. As learning pilots we must adhere the rating limitations as set forth by the United States Hang Gliding and Paragliding Association.

5.03 Recommended Operating Limitations for Beginner Pilots:

- A. Should exceed these limitations only after demonstrating complete mastery of the required Beginner proficiencies, and only after acquiring a full understanding of the potential problems and dangerous situations which may arise from exceeding these limitations.
- B. It is highly recommended that all flights be made under the direct supervision of a USHGA Certified Basic or Advanced Instructor.
- C. Should fly only in winds of 12 mph or less, with gust differential of 5 mph or less.
- D. Should foot launch only on slopes of 3:1 to 6:1, where wind is within 15 degrees of being straight up the slope.
- E. Should launch only when there are no obstructions within 60 degrees to either side of intended flight path, and when pilot may fly straight out from launch to landing with no need to maneuver and no possibility of over-flying the landing area.
- F. Should maintain flight heading within 15 degrees of directly into the wind.
- G. Should fly appropriate sites so as to maintain altitude below 100' AGL.

6.02 Recommended Operating Limitations for Novice Pilots

- A. Should exceed these limitations only after thoroughly mastering all required proficiencies, and after acquiring a full understanding of the potential problems and dangers involved in exceeding these limitations.
- B. It is highly recommended that all flights be made under the direct supervision of a USHGA Certified Basic or Advanced Instructor or Observer.
- C. Should fly only in smooth winds of 18 mph or less and gusty winds to 11 mph.
- D. If foot launching, should launch only on slopes 2:1 to 7:1, where wind is within 25 degrees of being straight up the slope.
- E. Should maintain heading within 90° of directly into wind, and within 45 degrees of directly into wind below 60' AGL.
- F. Flight speed. Should not attempt to fly slowly when encountering lift, but instead, concentrate on maintaining attitude, heading, and airspeed. Slow flight must be preceded by stall experience at 500'

7.02 Recommended Operating Limitations for Intermediate Pilots

- A. Should fly only in winds of 25 mph or less, with gust differential of 10 mph or less.
- B. Should initiate downwind turns only with 500' of clearance outward from the hill or ridge in winds above 18 mph, and 300' of clearance in winds above 10 mph.

C. Upon mastering the above skills, an Intermediate Pilot should pursue new maneuvers, sites and conditions with the guidance of a USHGA Certified Advanced Instructor or Observer.

Developing Judgment and Personal Growth

Every student pilot must develop physical, intellectual and emotional skills while earning hang gliding ratings. Rarely does an individual have average capacity in all three areas. We tend to depend on one or two to get us through other life's challenges. The proper progression of experiences and goals that develops these skills are:

- 1) Choosing smooth wind, low altitudes and ideal sites and situations so that **control skills** are mastered. (physical) and being persistent through learning plateaus (emotional).
- 2) Moving to higher altitude more challenging sites in smooth conditions (physical) so that **mountain launching, strategic flying and landing approach skills** are mastered. (intellectual)
- 3) **Exercise personal limits as you hone judgment** for the safety margins (intellectual) required to fly in higher wind, closer to terrain, at slower speeds, and perform advanced maneuvers (physical) such as smooth lift soaring. This means saying no to potential flights. (emotional)
- 4) Choosing to fly in increasing thermal or variable conditions till you can handle greater turbulence or change comfortably to **develop the art** of flying higher, longer and farther. (integration of all)

References and Recommending Reading

“How to Become a Weather Guru” and all the Oregon Hang Gliding website weather links
<http://www.oregonhanggliding.com/links.shtml>

How long is the coast of Great Britain?
<http://www.math.vt.edu/people/hoggard/FracGeomReport/node2.html>

Application of Fractals – Weather
<http://library.thinkquest.org/26242/full/ap/ap19.html>

Weather Forecasting
A policy statement of the American Meteorological Society as adopted by the Council on 13 January 1991
<http://twm.co.nz/wforcstg.html>

YES I Can! Science Team, Faculty of Pure and Applied Science, York University
<http://www.space.gc.ca/asc/eng/educators/resources/mars/grade5-atmosphere.asp>

What is the marine push?
http://www.komotv.com/weather/faq/marine_push.asp

Jet Stream, an Online Weather School
http://www.srh.weather.gov/srh/jetstream/mesoscale/tstrm_intro.htm

Meteorology and Flight Second Edition Tom Bradury 1996 A & C Black Ltd
This is an excellent volume on flight weather dynamics for the very interested amateur meteorologist and pilot. You will find almost everything you need to know about the general principles of forecasting the weather we fly. Of course, meteorology is very specific to geography so general principles must be applied with local knowledge.
<http://www.amazon.com/>

University of Illinois WW2010 Weather Tutorial
<http://ww2010.atmos.uiuc.edu/>

Oregon Weather: A State of Extremes George Taylor, Raymond R Hatton
http://www.ocs.oregonstate.edu/page_links/publications/weather_book/weather%20events/Hot%20weather.pdf

Wadsworth Publishing – Excellent academic meteorology textbooks can be found at this publisher website.
<http://www.brookscole.com/>

Soaring Society of America. The Soaring Society of America is an organization that developed in 1932 to foster and promote all phases of soaring, both nationally and internationally.

<http://www.ssa.org/>

Encyclopedia Britannica Learn more about your world from this excellent educational site the provides authoritative review articles <http://www.britannica.com/>

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Aviation Weather NASA – An excellent overview and tutorial of the weather that effects all pilots <http://virtualskies.arc.nasa.gov/weather/tutorial/tutorial1.html>

Meteorology Today Ahrens, C. Donald, Fifth edition.

PHYS-255 Meteorology UW-Stout Physics Department <http://physics.uwstout.edu/wx/Notes/ch6notes.htm>

Lyndon State College Survey of Meterology Nolan Atkins

<http://apollo.lsc.vsc.edu/classes/met130/>

<http://www.uwsp.edu/geo/faculty/heywood/GEOG101/winds/>

Weather Patterns Associated with the "Albuquerque Box" Mike Ford, Lead Forecaster

<http://www.srh.noaa.gov/abq/feature/abq-box.htm>

Geography 110 Introduction to Meteorology Joel Michaelsen Winter 2005

http://www.geog.ucsb.edu/~joel/g110_w05/

MetEd by the Comet Program <http://www.meted.ucar.edu>