Pilot Manual

4- Weather part II

Association of Paragliding Pilots and Instructors

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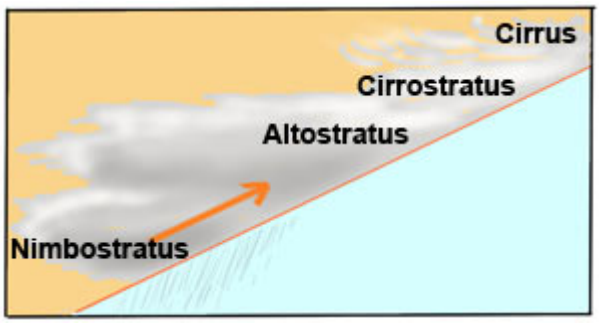
4.1 - The fronts

Fronts belong to meteorological situations that prevail in low pressure systems. (See Polar Front). When two air masses of different origin, and therefore different temperature, meet, we see most of the time clouds and rains is this well defined limit known as: front.

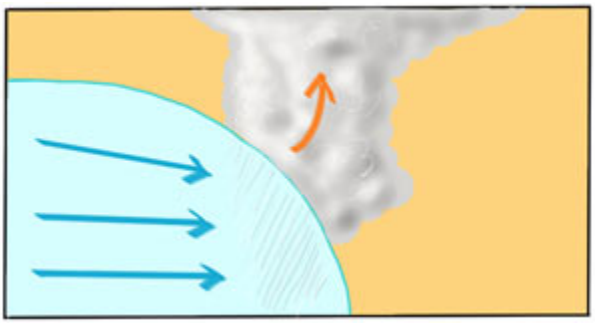
4.1.1 Warm Front

If a mass of warm air rushes into a mass of cold air, it glides upwards along the cold air; this makes the air mass cool down and brings it to its dew point. The warm front involves persistent clouds and rain.



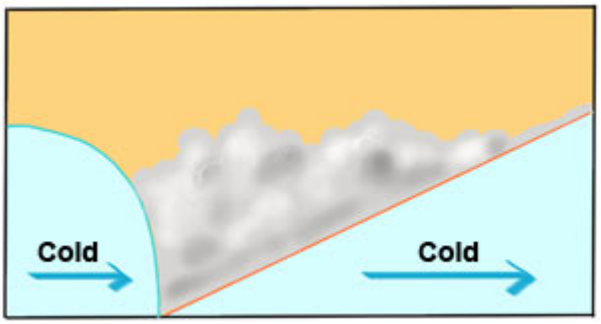
4.1.2 Cold Front

If a mass of cold air crushes into a warm air mass, being heavier it seeps in the warm air and, as if it was a lever arm, lifts it vertically; this cools down the air mass and leads it to its dew point. The cold front implies stormy clouds and rain.

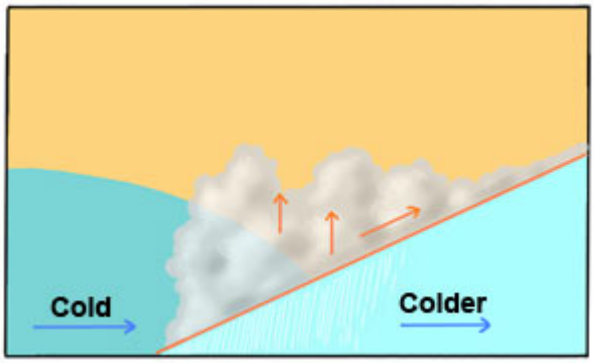


4.1.3 Occlusion

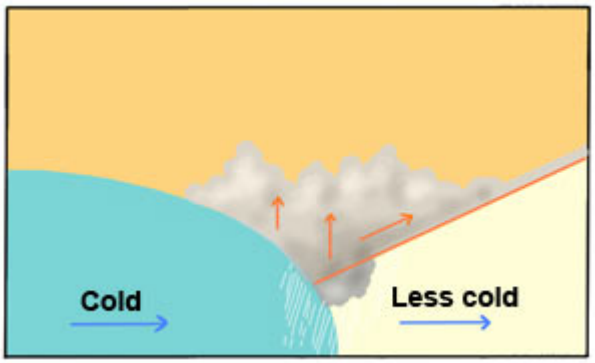
At the end of a low pressure system, the cold front overtakes often the warm front, this is called occlusion. Depending on the temperatures in conflict, the occlusion may have a warm or a cold front character.
Hazards: severe turbulence!



Occlusion warm front character



Occlusion cold front character



4.2 - High and low pressure systems

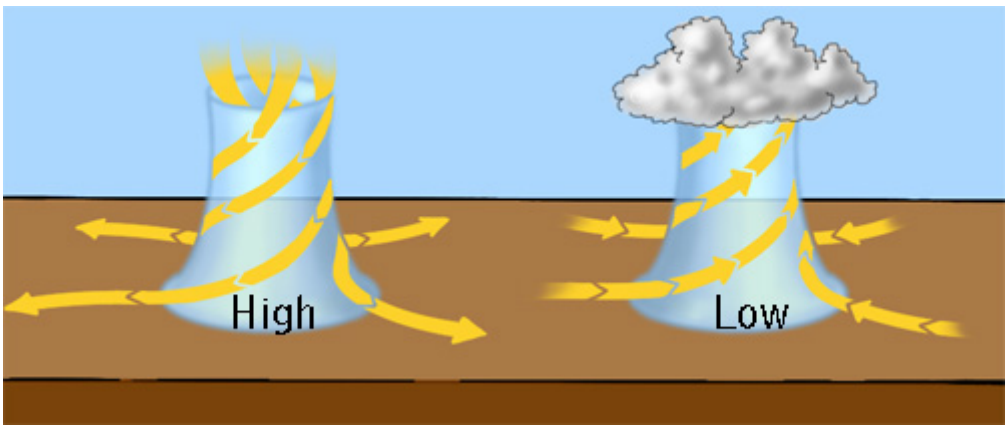
4.2.1 Thermal origin of high and low pressures

The suns rays travel in straight lines to the earth. The angle of attack of the sun's rays is more perpendicular to the Earth's surface at the Equator than at the poles. The suns rays are hotter where they hit the earth directly at the equator. They hit the earth at a low angle at the poler regions making them more spread out and giving less heat.
The warming of the Earth's surface is not only due to the sun's rays but also to the type of surface. Snow reflects the sunlight whilst a ploughed field absorbs the heat of the sun and gives off radiation, heating the air above. Being different, the warming of the Earth's surface creates different pressures. In warm places the air heats up expands and rises, the pressure and density in these places are lower than the air above cold surfaces.

- **Low pressure** (cyclone): warm air rises ⇒ it cools ⇒ it reaches its dew point ⇒ cloud formation ⇒ bad weather. Air flows in an anti clockwise direction in the Northern hemisphere and clockwise in the Southern Hemisphere. In a low pressure the air masses above are moving apart causing a vacuum which is filled from the air rising below.
- **High pressure** (anticyclone): the air masses above are coming together, cold air sinks and spirals downwards. (Clockwise in the Northern hemisphere, anti clockwise in the Southern; this phenomenon is called "subsidence" ⇒ in downward movement this air warms by compression along the dry adiabatic temperature curve ⇒ clouds dissolution ⇒

stable, sunny weather.

- **Pressure gradient** - the airflow will try to move from a high pressure area to a low pressure to fill it.



4.2.2 General circulation of the wind on the planet

As we have seen, the Earth's surface is heated more strongly at the equator than at the poles. So there reigns a low pressure system because air masses rise. A small part of this air continually rising is taken to high altitude and moves poleward. Most of this air sinks to 30 degrees latitude, part of it goes back to the South in order to replenish the equator ascent, and the other part goes up towards the North.
Therefore, at 30° latitude, there is a constant subsidence that generates fine weather with little wind, and we understand better the existence of the famous Azores anticyclone. Due to the **Coriolis force** caused by the rotation of the Earth, the air masses do not move in a straight line but always with a rightward movement in the Northern Hemisphere. This originates the steering "trade winds" in the tropics, the "westerly winds" under our latitudes and the "polar easterlies" beyond 60° north latitude. These last winds greatly influence our weather, especially during winter because the cold air masses come into conflict with warmer air masses, causing front situations.

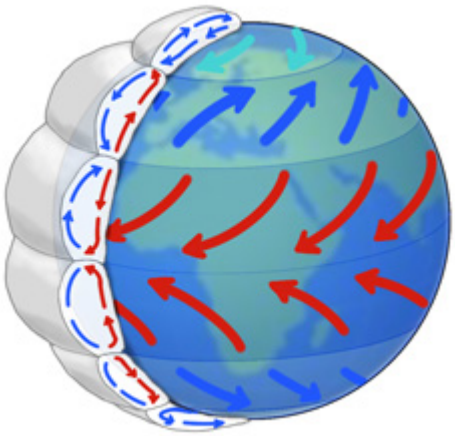
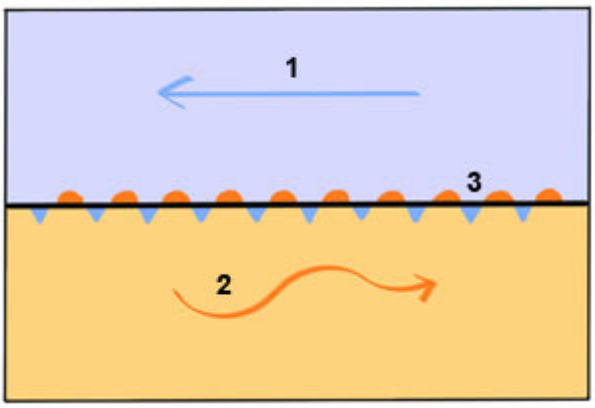


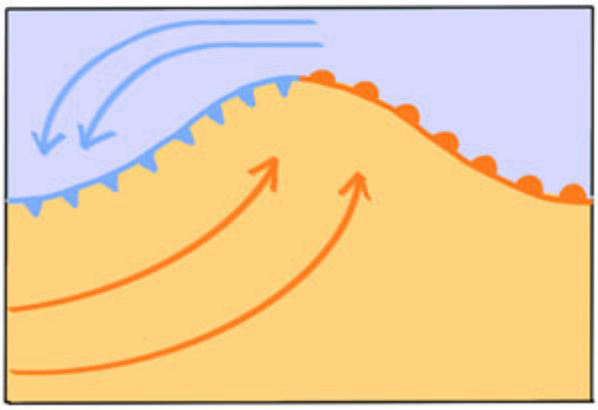
Fig. 3-37: Wind circulation on the planet.

4.2.3 The dynamic low pressures

The temperature differences between oceans and continents and between warm and cold oceans, influence the general circulation of air. Some warm and humid air masses come in contact with others which are cold and dry. At about 60 degrees north latitude there is a clear dividing line between the cold winds from the east and the warm winds from the West. This line is called the polar front. The different air masses entangle like gears along this boundary.

Fig. 38 & 39: *Development of low dynamic pressures: gear of air masses.*
1*: Polar Wind from East: cold;* ***2****: Wind from West: warm;* ***3****: Polar front-line 60° N*





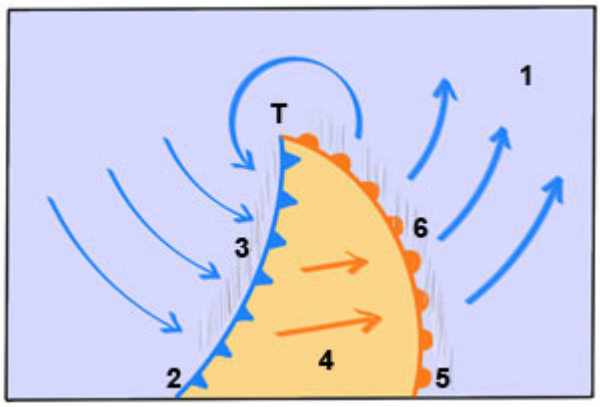
Within the low pressure system, the air of surrounding high pressures comes to fill the vacuum. Two air masses of different temperatures will begin to rotate clockwise (since the air is deflected to the right at high pressure systems because of the Coriolis effect, by the gear phenomenon the flow goes towards left on the low pressures). The sinking of a warm air wedge

in the interior of cold air causes a decrease in the barometric pressure. Two fronts are therefore put in place, a warm front that moves slowly (about 20 to 25 km / h or 10 to 15 kts) (kts = knots) as it relies on a dense air, and a cold front advancing faster (about 35 to 50 km / h or 20 to 40 kts) as it relies on a less dense mass of warm air. After a day or two we can already observe the advance of the cold front.

Fig. 3-40: *The low pressure center*

Fig. 3-41: *Sectional view of Fig. 3-40*

1*: cold sector;* ***2****: cold front;* ***3****: short rains, storms;* ***4****: warm sector;* ***5****: warm front;* ***6****: Persistent rains*



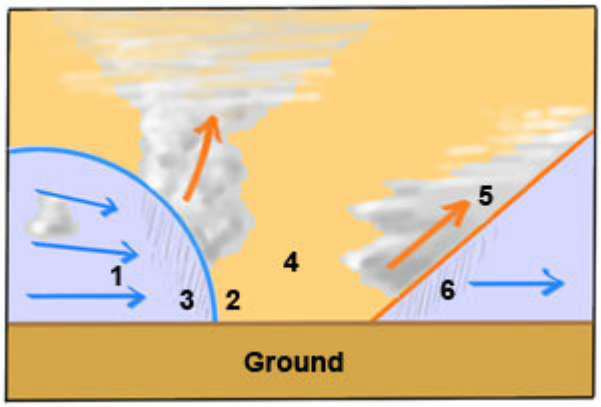
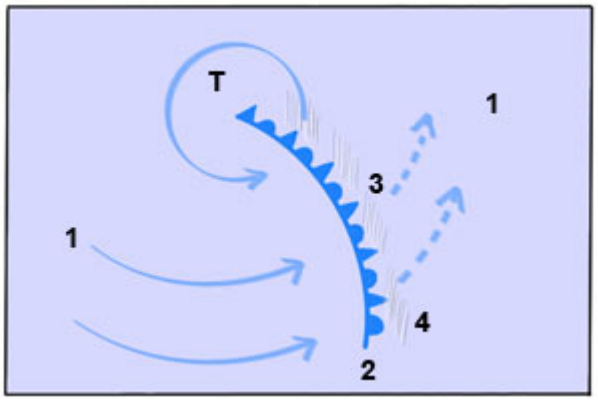
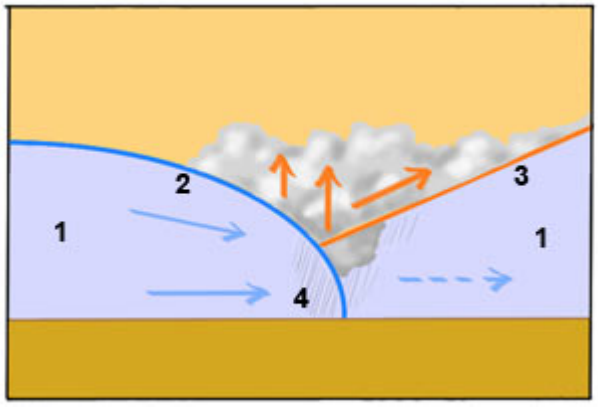


Fig. 3-42: Occlusion

Fig. 3-43: *Sectional view of Fig. 3-42*

T*: low pressure area;* ***1****: cold;* ***2****: cold front;* ***3****: warm front;* ***4****: precipitation*



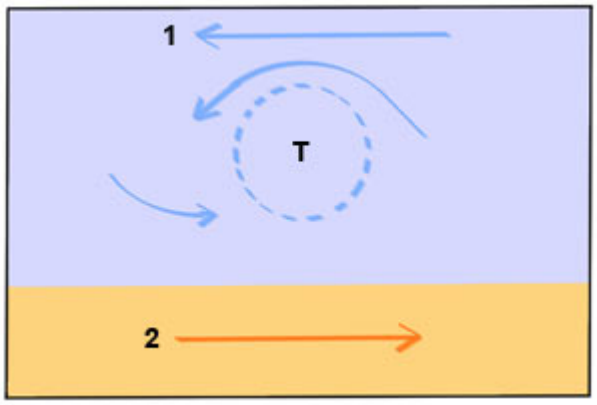


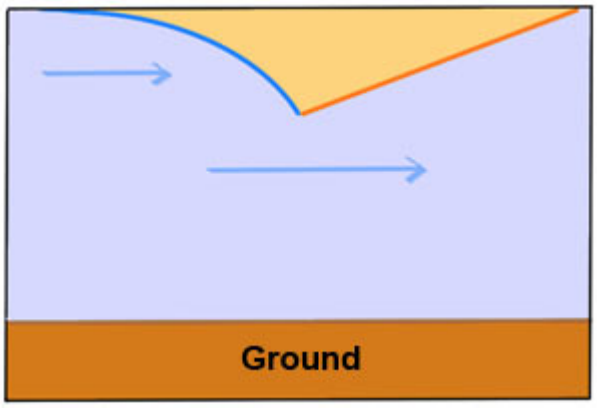
Ahead of the cold front, there is a great danger of severe turbulence. After 3 or 4 days an occluded front may occur, the cold front has overtaken the warm front, the pressures get in balance and the whole pressure system loses its force. Dissolution: the warm sector being pushed upwards and the cold taking place below it, there is no more reason to have masses of rising air. Moreover the pressures are balanced with neighboring anticyclone systems. The cycle is completed.

Fig. 3-44: Dissolution

Fig. 3-45: *Sectional view of Fig. 3-44*

1*: cold, East polar wind;* ***2****: warm, West wind*





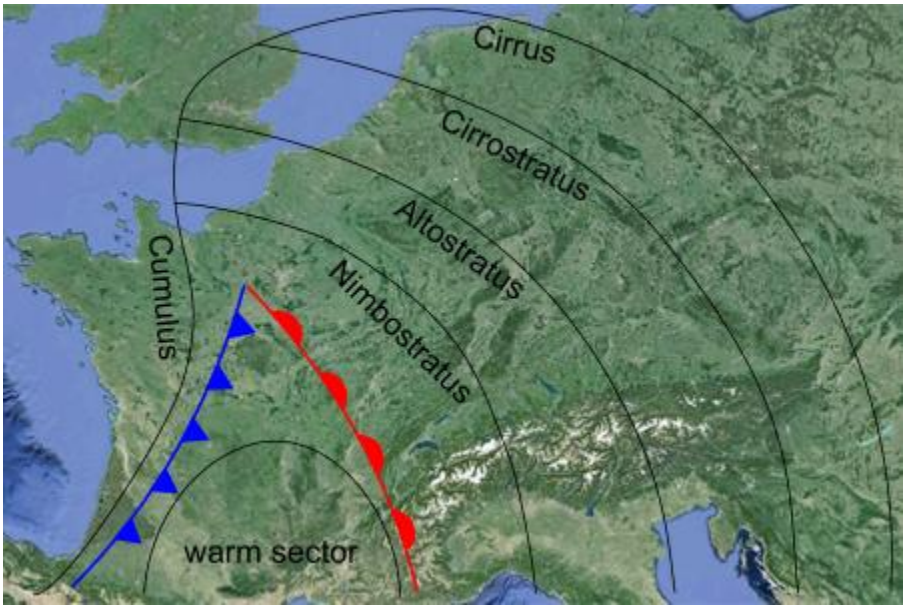


Fig. 3-46: *typical clouds during a passage of a polar front wave.*

Photo 3-15: ***Cirrus*** *clouds announced a warm front approaching. They gradually become denser and become a layer of* ***cirrostratus*** *.*

Photo 3-16: *This layer becomes thicker and the ceiling falls.* ***Altostratus*** *are formed. Cloud base goes down again. We observe the first rains. Altostratus become …*

Photo 3-17: *Nimbostratus Rainfall becomes more important and lasting several hours. Shreds of* ***stratus*** *clouds cover the sky. After the passage of the warm front rainfall decreases ….*

Photo 3-18: *The air temperature rises. We are now in the warm sector.* ***Stratocumulus*** *Lightweight move across the sky.*

Photo 3-19: *We can notice magnificent* ***storm clouds*** *of summer cold front..*

Photo 3-20: *After a relatively short time, the sky is completely covered. Storms and turbulence accompanying the passage of the cold front. The wind turns west to east.*

Photo 3-21: *The sky cleared in the polar air behind the cold front. This promotes the formation of* ***cumulus.*** *Sunny moments interspersed with scattered showers and residual thunderstorms..*

Photo 3-22: *Towards evening and also with the arrival of time trolling, the cumulus become flatter, then become* ***stratocumulus*** *which disappear slowly. The lull due to the high pressure happens, will be more or less long before the arrival of a new wave of the polar front.*

4.3 - The wind

The wind is the result of the re-balancing of pressure systems. Air masses always move from surfaces of high pressure to surfaces of low pressure.

4.3.1 Wind Speed

- **Unit of measure**: node, KT (= nautical mile per hour), m / sec (or km / h), 1 nautical mile = 1.852 km
- Equivalence of knots into km / hour (approximate formula): (kts x 2) 10%
- **Measuring instrument**: anemometer. For measurements at high altitude, radio sensors are used.
- **Graphical symbols in synoptic weather maps**: The long line indicates the origin on the map, North always on the top. The perpendicular line gives the velocity of the latter (large perpendicular line = 10 knots, small = 5 kts).

Example: - Southwest wind, 15 kts

- north wind, 30 kts

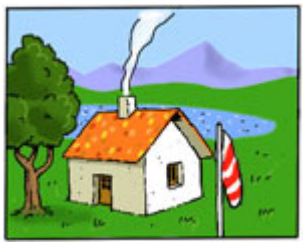
Links with practice - **caution**: the average is given in the wind speed data. Therefore one must always count on gusts 1.5 times higher than the given speed.

Example: Weather Information: west wind 30 km / h, maximum gust peak possible: 45 km / h.

The greater are the differences of pressure and the tighter are the isobar lines on the weather map and the stronger is the wind.

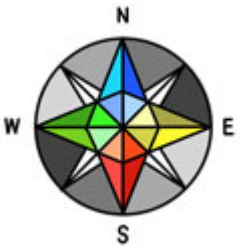
difference of 5 hPa / isobar	wind speed		
600 km	light breeze	2 Beaufort	5 kts
500 km	moderate wind	4 Beaufort	13 kts
400 km	moderate wind	5 Beaufort	18 kts
300 km	strong wind	6 Beaufort	24 kts
200 km	violent wind	7 Beaufort	30 kts
500 km	storm	9 Beaufort	44 kts

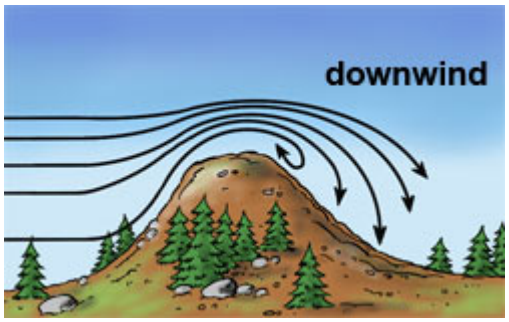
gaps between isobaric lines	indications	wind
small	big pressure drop	strong
big	uniform pressure distribution	low

	degrees Beaufort	m / s	Trees	km / h	indication	kts	wind conditions
	1	0.3 - 0.5	motionless	1 - 5	wind direction indicated by the smoke	1 - 3	low
	2	1.6 - 3.3	rustling leaves	6 - 11	perceptible wind on your face	4 - 6	low

	3	3.4 - 5.4	movements of thin branches	12 - 19	flags begin to float	7 - 10	low
	4	5.5 - 7.9	movements of all branches	20 - 28	Uprising isolated papers and dust	11 - 15	moderate
	5	8.0 - 10.7	movements of small trees	29 - 38	scum on water	16 - 21	moderate
	6	10.8 - 13.8	movements of large trees	39 - 49	ringing in the vicinity of power lines and telephone	22 - 27	strong

• **Influence of landforms on wind speeds**: the speed of the air flow is accelerated on the ridges by the Venturi phenomenon.



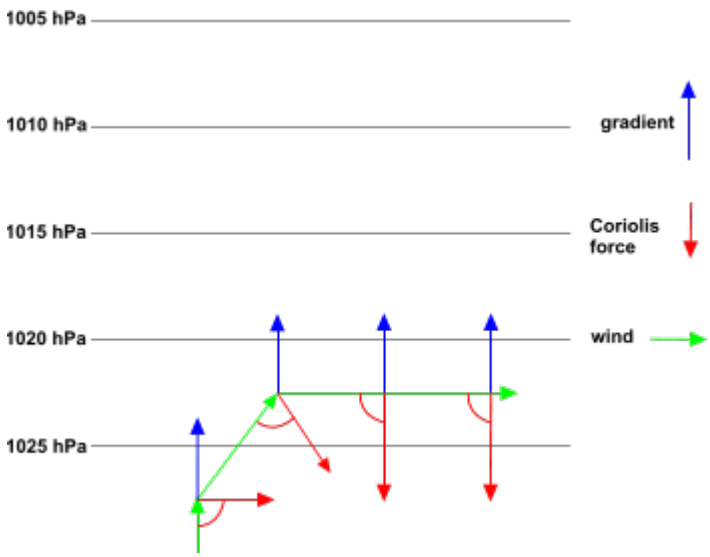


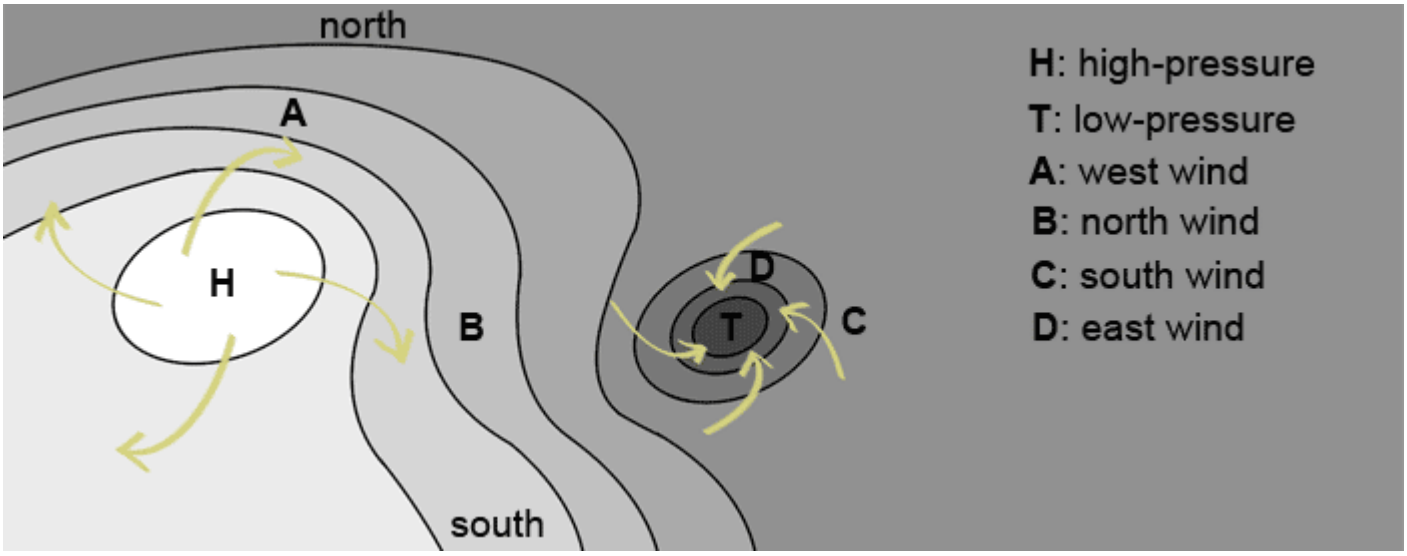
Links with practice:
- **Precautions when starting on a ridge**: with strong wind one must takeoff downstream and keep a safe distance from the ridge and peaks around because after takeoff one can be lifted up until the altitude of the ridge and be dragged along the leeward side.
- When **flying over a ridge** we can expect stronger winds.
- The topographic narrowing of a valley also has a direct effect on the increase of the wind speed (see the Venturi effect).

4.3.2 Wind Direction

It is always shown the source of the wind and not its direction. A west wind comes from the west and hits the east slopes. Just like the mountain wind comes from the mountains and goes toward the valley. Southwest wind with a speed of 36 km / h is abbreviated in weather forecast jargon like: **225/20** (225° ⇒ SO, 20 kts ⇒ 36 km / h).

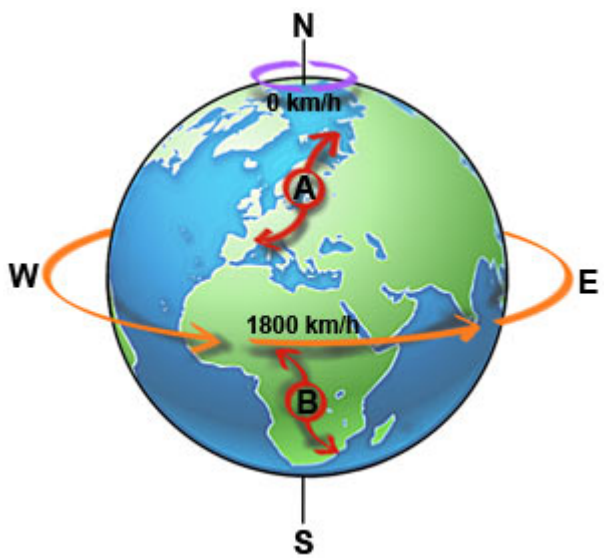
Under the influence of the only force of pressure, the air would move only perpendicular to the isobar lines, ranging from high to low pressures, as rain on the slope of a roof. The most important force among the forces acting on the air is the Coriolis force. It prints a curve shape in any trajectory due to the rotation of the Earth. This force is perpendicular to the movement. Deviation takes place toward the right of the trajectory in the Northern Hemisphere and to the left in Southern Hemisphere. When, in a particular place, the wind reaches a constant speed and direction, which occurs daily on vast extensions of our planet, there is no more acceleration of air masses. This means there is a balance between the pressure force and the Coriolis force. The wind and the Coriolis force being perpendicular, the wind is by this time “parallel” to the isobars. In fact, there is always a certain angle between the isobars and the wind direction, otherwise the high pressure systems would never rush in to fill the area of lower air pressure.





4.3.3 he Coriolis effect

The Earth rotates at equator with a velocity of 1666 km / h. The Earth’s rotation with 40,000 kilometers from west to east lasts 24 hours. At the same time the air particles of the atmosphere are also accelerated to this speed of 1666 km / h. Conversely, the speed of the Earth’s rotation at the poles is 0 km / h.

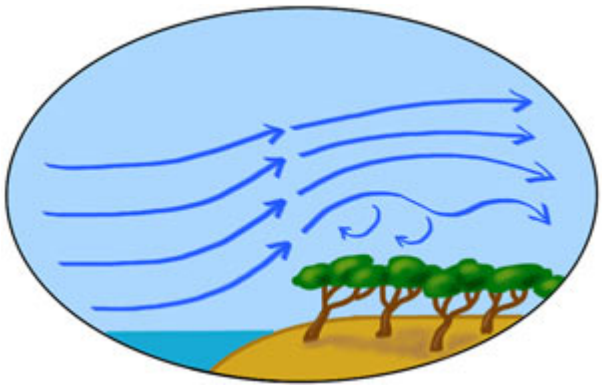


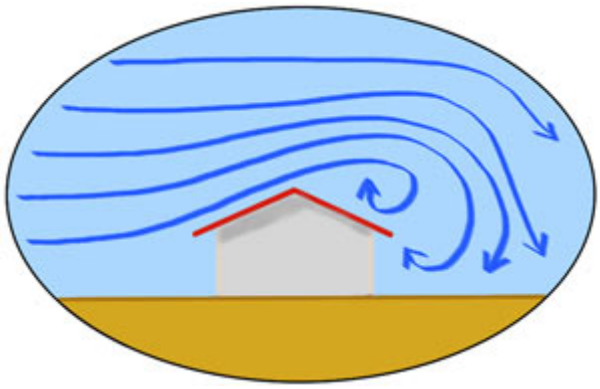
The Coriolis force acts when an air mass changes its latitude degree, meeting air masses that move faster or slower than it. This can be shown according to the following example: A passenger descending from a moving train has to run a few meters before stopping for he has stored the train speed (inertia). The same happens with the air particles moving from one point towards the poles, they carry with them a greater rotation speed and are ahead of the Earth’s rotation as the passenger who jumped from the moving train and, for a moment, goes faster than the train to stop afterwards. This gives the Northern Hemisphere winds the tendency to turn right and in the Southern Hemisphere the tendency to turn left. Similarly, the air particles that start from the pole towards the Equator have almost zero velocity at the start. The Earth turning from West towards the East follows exactly the same tendency to turn right.

4.3.4 Turbulence

If the laminar flow of an air mass is disturbed, there is formation of turbulence. This turbulence has two causes:

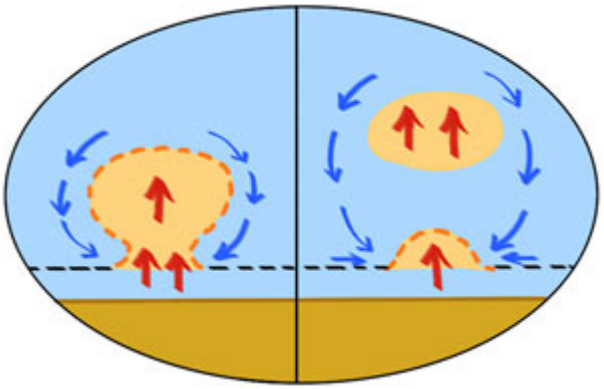
• **Friction:** it refers to dynamic mechanical turbulence. Depending on the shape and nature of the soil, the air masses from the lower layers are hindered, disrupted and deflected. Much less turbulence is expected over flat terrain such as a lake, than over an irregular field. In addition, near the ground, the air meets multiple barriers in different forms that cause eddies taken then by wind and resulting in a disturbed and turbulent atmosphere.

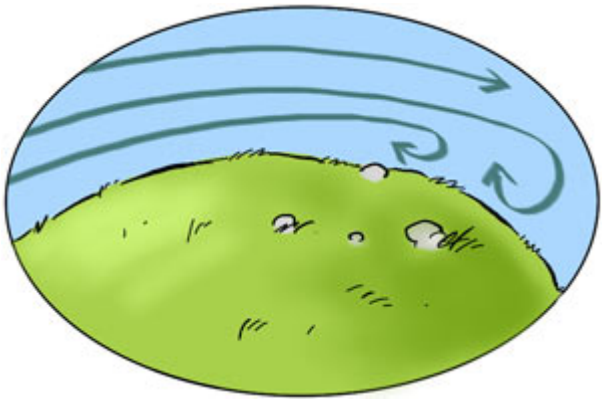




Links with Practice: Avoid downwind landings close to trees or houses.

• **Temperature:** it refers to thermal turbulence. When an air bubble is rising, it disrupts the flow of air of the prevailing wind. Moreover, it creates a depression above the ground which tends to balance itself by sucking the surrounding air.

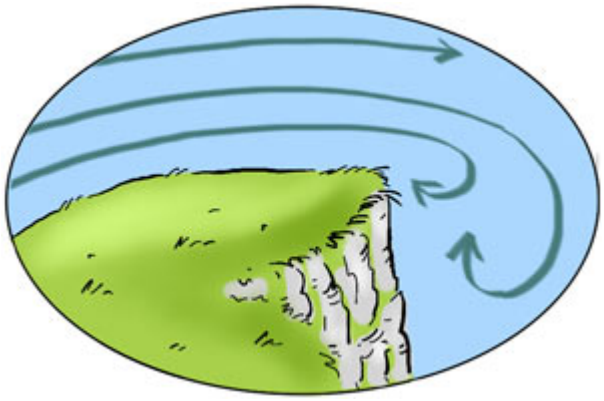




• **Downwind situation:**
Rotors are created on the leeward side of objects such as houses, trees, etc. ... it may even be hills or the whole mountains.

Links with practice: On the leeward side of a ridge, without relevant thermal, it is possible to notice a headwind. Warning: this is a deceptive wind because it is due to a rotor effect and immediately after takeoff the wind suddenly descends the slope. For this reason, one must always consider the general direction of the wind. This must be considered for instance at an exposed point at the top of the ridge under which we want to take off. In addition, during the ascent to the flight site, one must constantly observe the wind evolution.

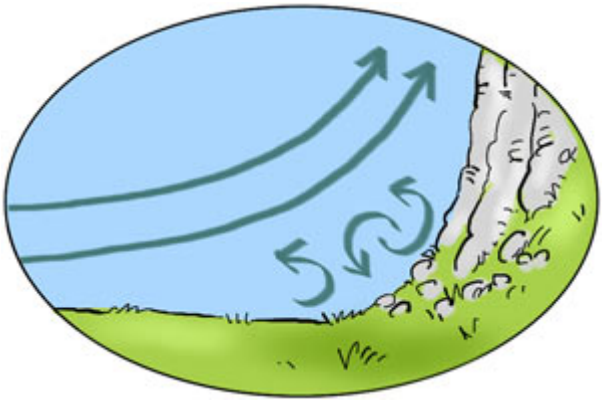
The rotors increase in size and strength in proportion to the wind speed increase. These rotors can reach several hundred meters in length.
The shape of the downwind ground also plays a role on the rotors strength. The steeper the downwind ground, the stronger is the turbulence. The strongest turbulences are generated when the windward and leeward slopes are steep.



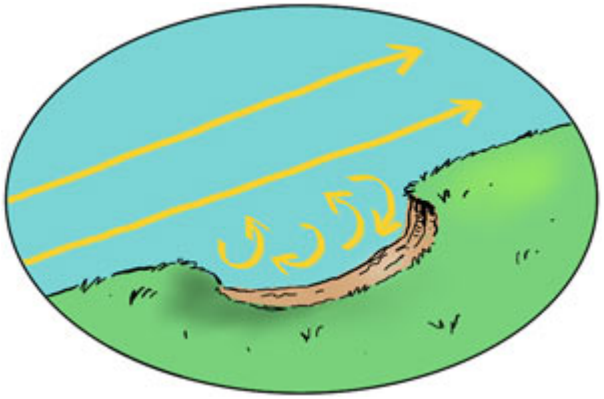
Links with practice: Downwind turbulences responsible for wing tuck can occur with measured wind speeds of only 10 km / hour.

Wind situations:

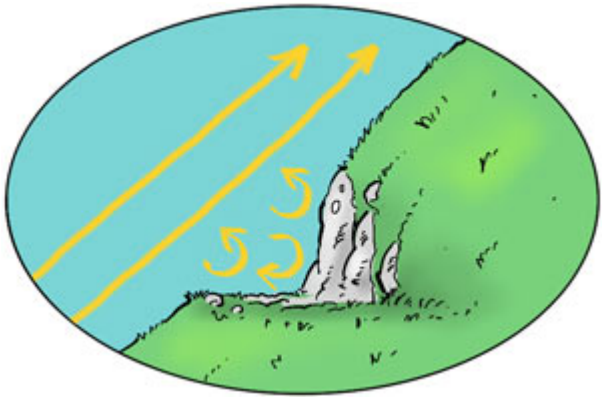
A windward side, exposed to wind, can also create critical rotors as those found in the leeward side. They are due to topographic changes, including:
- the foot of the cliff



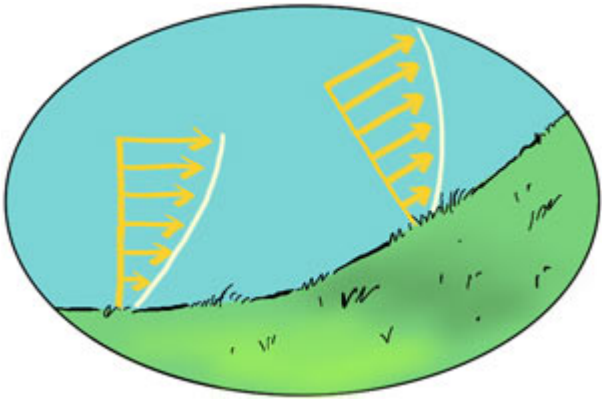
- depressions



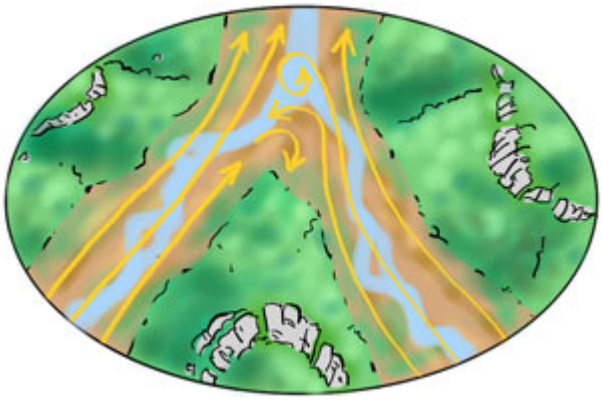
- terrace



Wind-shear situation:



Vertical: it is a change in the wind direction and strength when catching altitude. The wind decrease or increase with the altitude is called wind gradient. In the lower layers up to 300 meters above areas with high terrain roughness, there may be differences of more or less 20 knots per 100 meters. In general, we can say that in a plain surface the wind is weaker but more turbulent, given the ground obstacles, than the one reigning 300 meters above.

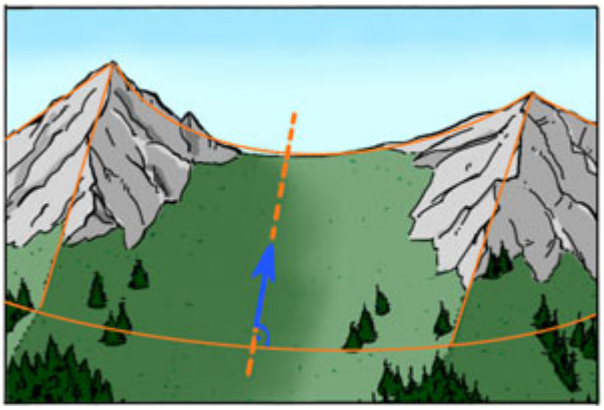


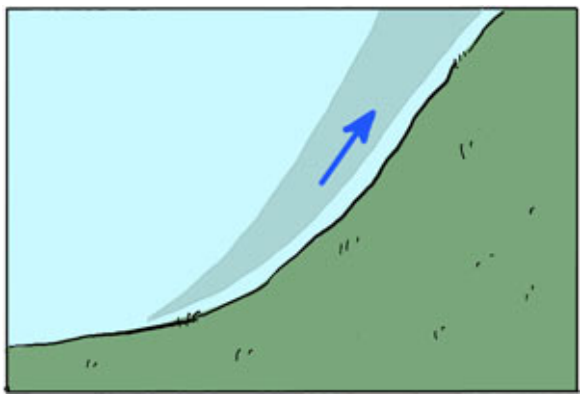
Horizontal: when two valleys meet (see diagram), or when two winds, one local and one dominant (see leeward thermal), meet, turbulence is generated.

4.3.5 Slope lift

We talk of a dynamic wind when an air mass collides frontally with an obstacle and can not avoid it laterally. Thus the air must move above the obstacle and causes an ascent in its center.
Both dominant winds and valley winds can cause dynamic lift on the slope. Whatever its origin, the differences in the character of this lift are minimal. Apart foehn, all winds with a speed of about 30 km / h are conducive to the soaring practice (dynamic lifts technique). But just as the wind speed, if not more, slope plays an important role. To optimize a slope flight it is therefore necessary to take into account:

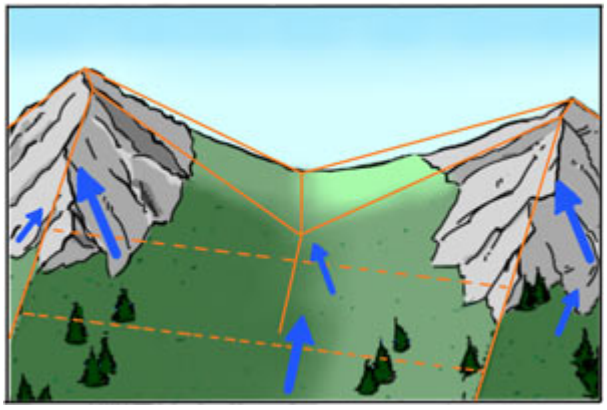
• **the orientation and width of the slope**
The best wind is created when the air mass hits the slope perpendicularly.
The wider the slope, the more the air masses must avoid it perpendicularly over a large area and the easier it is to use this slope for soaring practice.

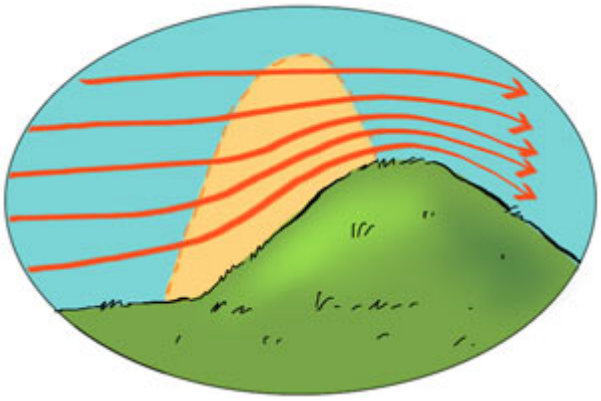




• **the height of the slope**
At the foot of the slope, where the wind speed is low, the upward surface is too little usable. With the altitude of the slope, the rising wind increases its speed and volume.

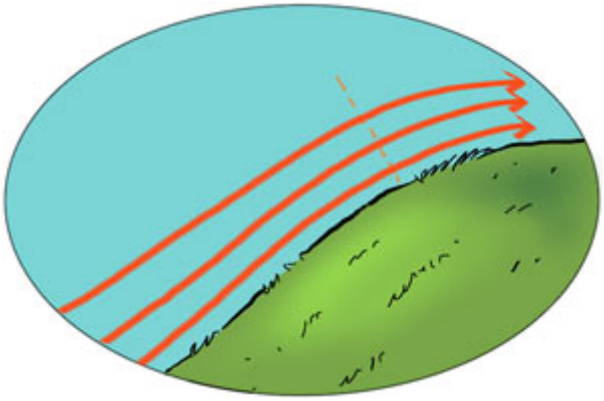
• **the slope profile**
If the wind hits frontally one side, it accelerates in the hollows that suck the air and reduces at the rough surfaces that repel it. When the wind comes from the side the opposite phenomenon happens, which is easily noticed on ridges and passes.



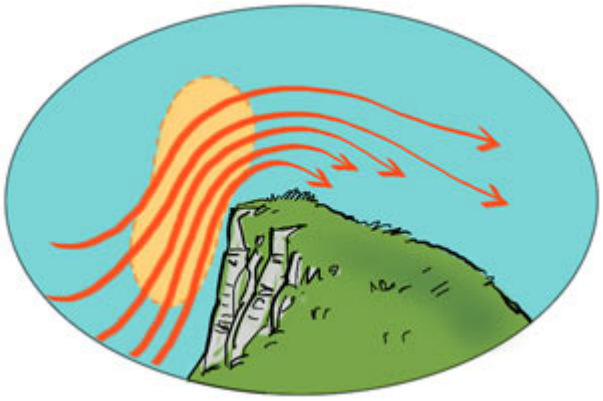


• **the slope inclination**
The size of the usable dynamic lifts depends on the slope inclination. With less inclination, the ascending area is more expanded in depth and the wind speed is lower. On a hill for instance, the good usable ascents are slightly ahead of the peak.

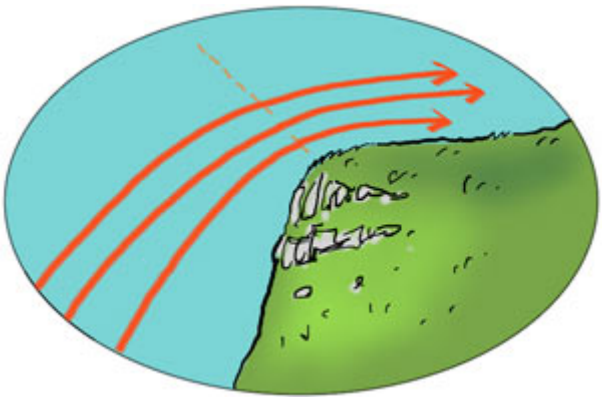
The weaker the inclination of the slope, the more the lift lies ahead of the peak.



The steeper the slope, the narrower is the lifting area and the stronger is the wind.

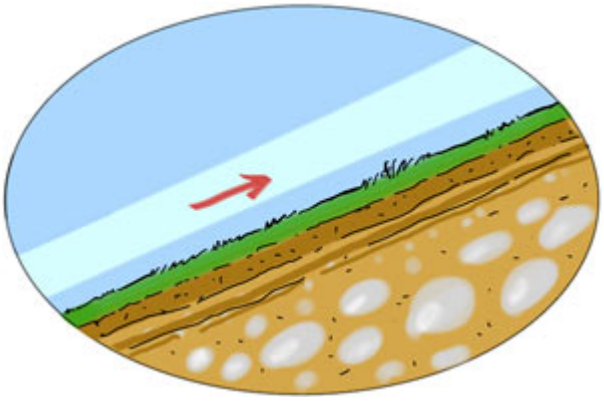


On a cliff like slope the lift lies ahead of the peak.

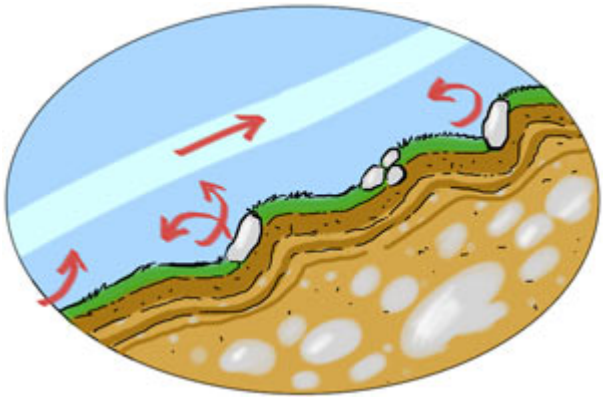


• the surface state of the slope

The surface state (texture) of the slope refers to the vegetation disposal and arrangement at the soil surface. If the slope has a regular inclination and a smooth texture one can find the best lifts at a distance of 10 to 20 m from the ground.

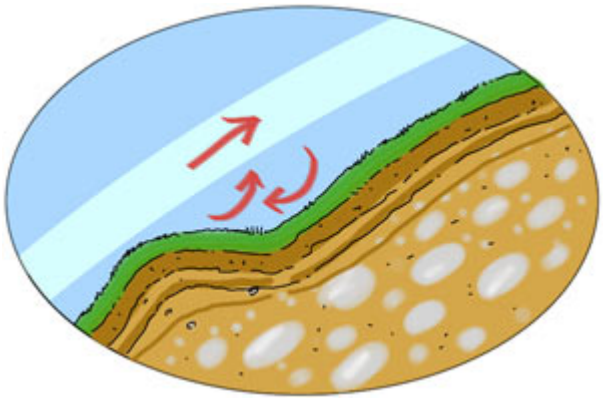


If, on the contrary, the ground is irregular the best lifts are at a greater distance and are smaller. This is explained by the presence of turbulence very near the ground which reduces the wind speed. **Links with practice:** Increase the safety distance in regard to the slope and other aircraft.

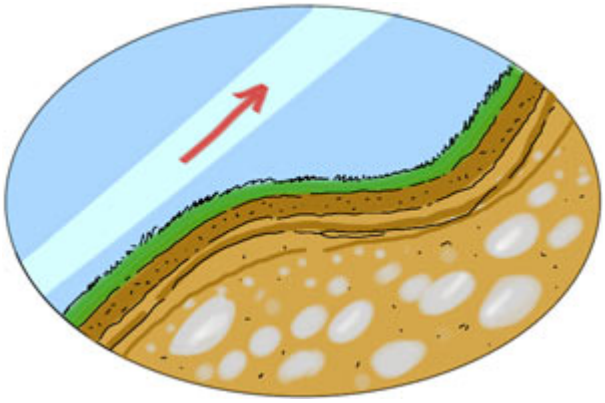


• the breaks in the slope profile

Breaks in the slope profile disrupt the updraft flow along the slope. We talk of temporary takeoff lift, if the slope becomes more regular the lift reattaches to the slope.



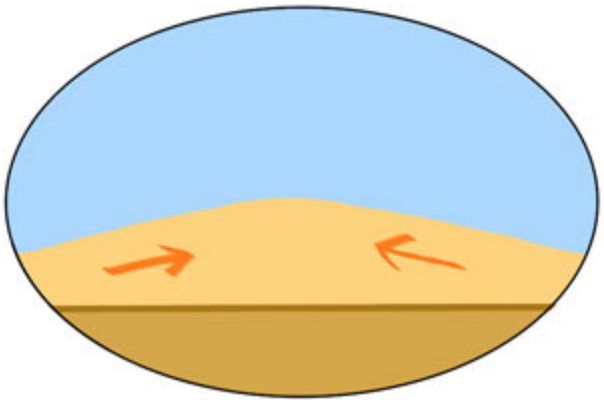
On the contrary, large terraces keep away the slope lifts.



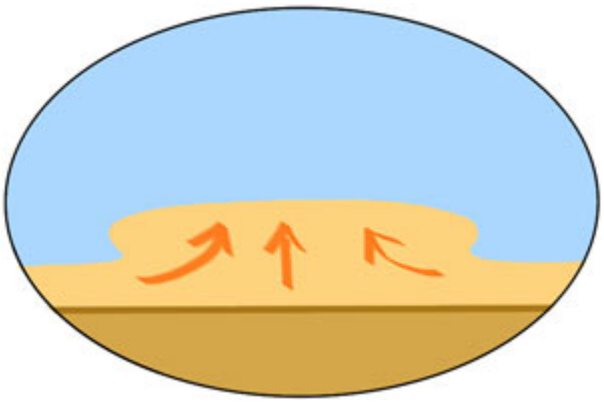
4.4 - The thermal

4.4.1 Origin

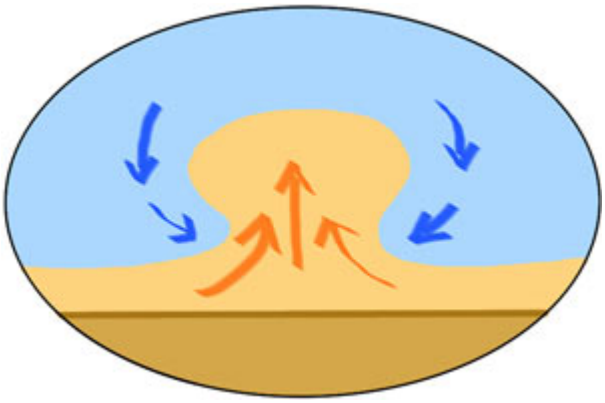
The Earth's surface gets warm by the sun differently depending on the nature of its surface (see 4.4.5).
Above the heated surfaces an air layer is formed which reduces its density by the temperature increase and forms a bubble which tends to rise.
This process is more active when the wind is low.

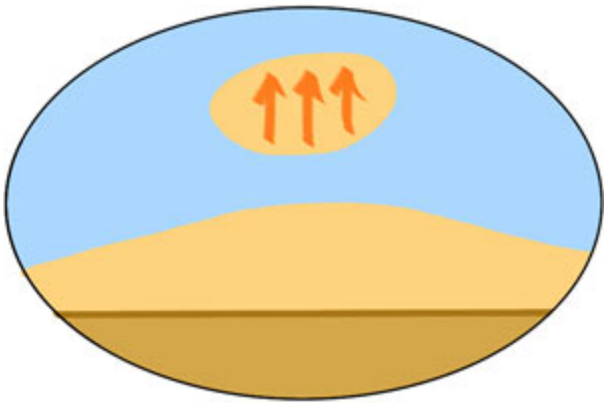


Because of friction at the start, this bubble remains close to the ground.



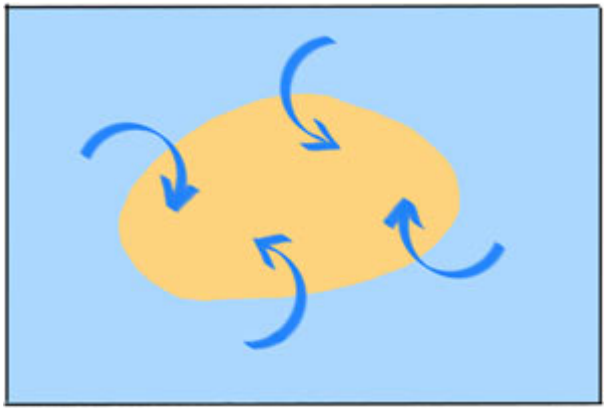
By a continuous warming, this bubble grows up, the repelled cold air descends along the bubble and therefore raises it.

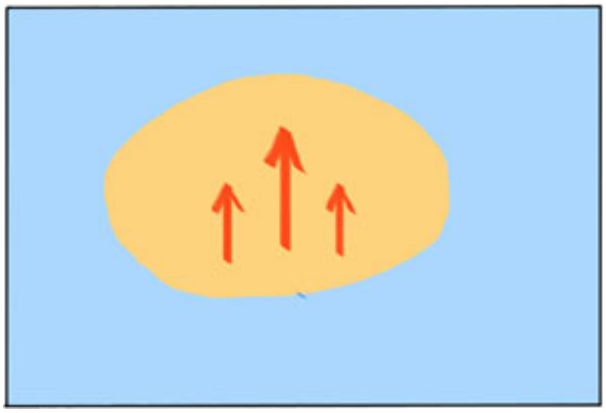




The pulse is triggered either by wind or vibration or by a continuous warming.
The higher the temperature difference between the bubble and the surrounding air, the faster the thermal bubble is rising.

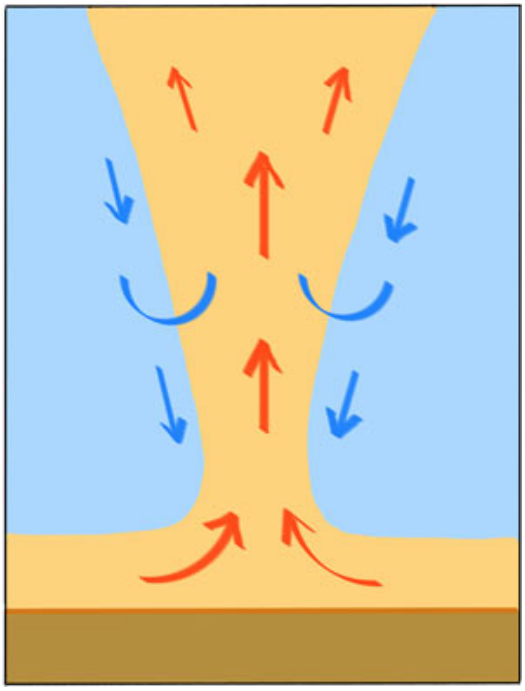
At the bubble edges the warm air mixes with the cooler surrounding air, and this causes turbulence.
Thus, by expanding, the bubble grows continuously with altitude but it cools down too.

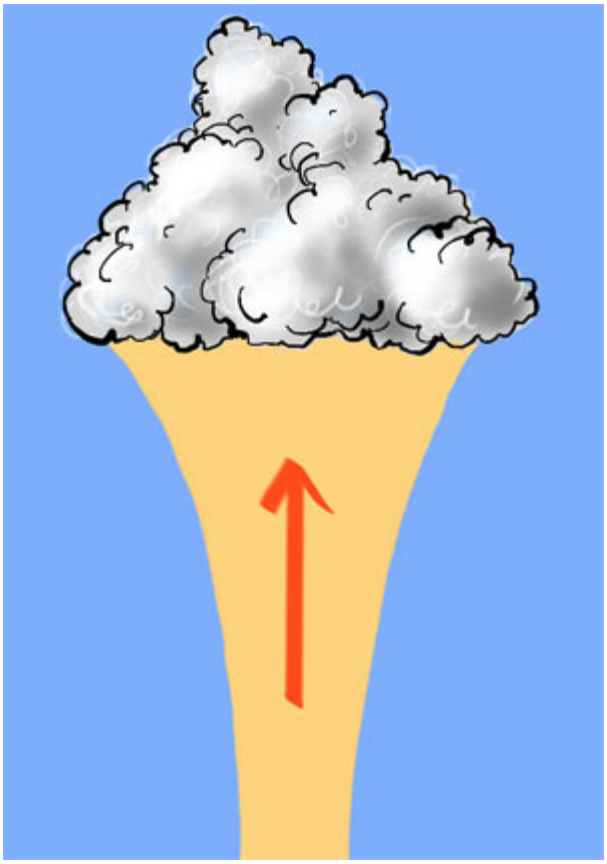




The upward rate in the center of the bubble is almost the double from the one at the edges.

The rising bubble of warm air draws the surrounding air at its base, thus forming a trail.
This helps the next bubble to rise and if the thermal conditions are good the upward flow of air is continuous forming a thermal column.
The diameter of this column is 20 to 200 meters near the ground and nearly the twice in altitude.
Several columns can come together to create large upward areas.



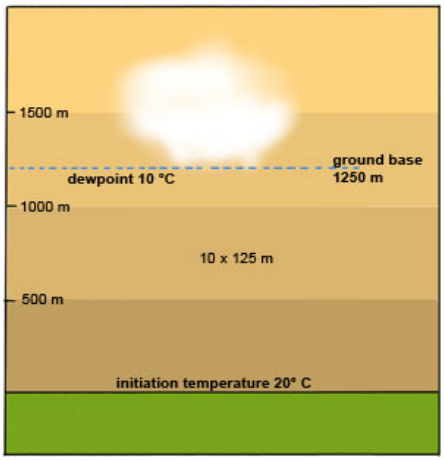


4.4.2 Cloud Formation

When rising warm air reaches its condensation level, it forms a cloud. The released condensation energy gives the bubble even more upward force.
Cumulus clouds formed by days of fine weather are reliable indicators of the thermal location.
A sufficiently formed cumulus cloud can draw the air directly from below even if there is no more warm air coming from the soil surface.

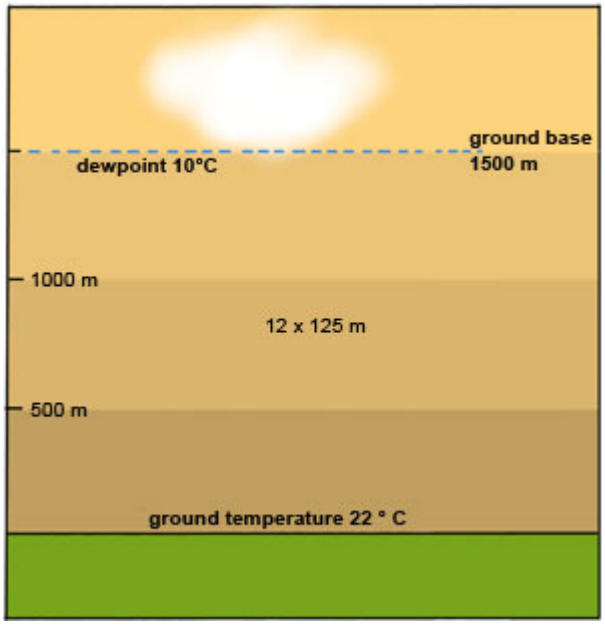
types of clouds	area & size horizontal - vertical		lifetime	forcefulness
Cu humilis	50 - 500 m	0.5 - 2 km	20 min.	until 3 m / sec
Cu congestus	0.5 2 km	2 - 5 km	40 min.	until 12 m / sec
Cb	2 - 20 km	3 - 12 km	100 min.	until 30 m /sec

Photo 3-26: ***cumulus humilis*** *: small cloud formations growing into balls with sharp and clear edges which testify a rising thermal activity. If the base of this formation is convex one can expect extremely strong thermals.*

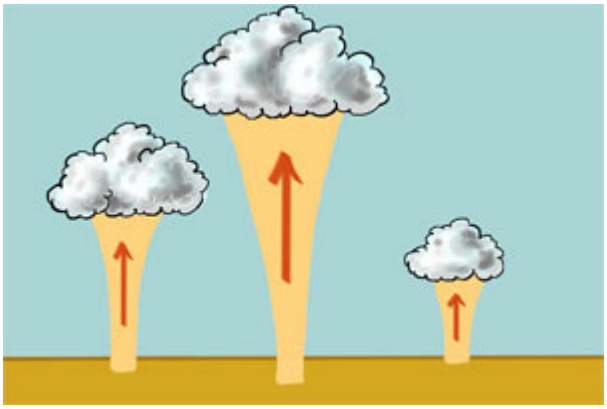


For an induction of the thermal process and thus the formation of clouds, there must be a precise temperature on the ground. It depends on the atmospheric state curve and on the relative humidity of the air near the ground.
If one knows the trigger temperature (= state curve + 3 to 5 °C) on the ground and the dew point temperature of the air mass it is possible to determine the altitude of the clouds basis by the approximate formula:
H = 125 x (Trigger temperature - dew point temperature).

In other words, for each Celsius degree of temperature rising on the ground, the cloud base rises 125 meters.
It is possible that the difference between the temperature of the rising air bubble and the dew point temperature of this air bubble is so large that clouds never form during the day.
This is called thermal blue. They are difficult to locate but there are still great to use.

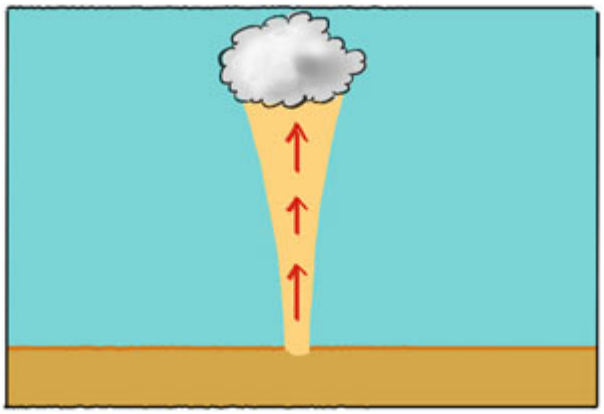


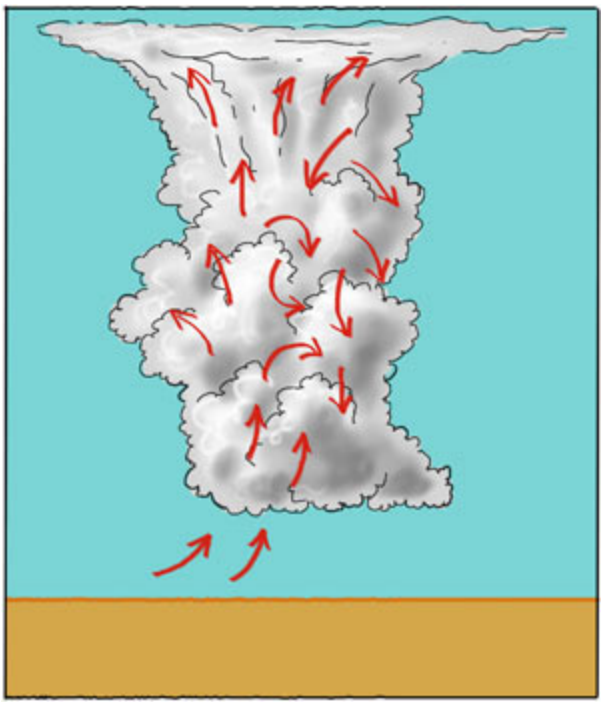
4.4.3 Upward force of the wind



The average force of the updraft increases more or less linearly till the cloud base. If the cloud base is at 2000 meters, the average ascent rate here is twice as large as at 1000 meters.
The best ascent rates are in the lower third of the convection area and also just below the cloud base (due to the condensation heat released) where the cloud is darker and convex.

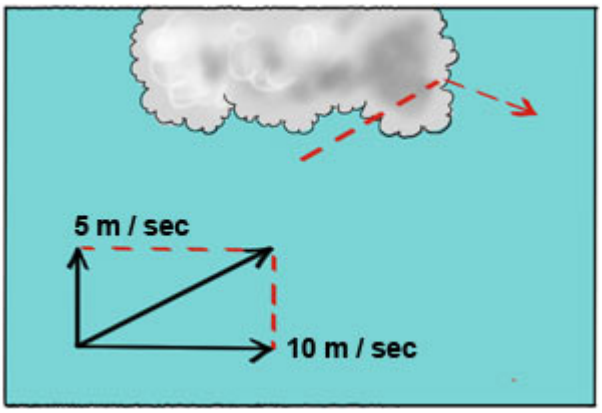
Warning: during unstable weather conditions or in stormy situations, harmless cumulus clouds can quickly turn into dangerous storm clouds. There may be a sucking of more than 10 m/s to several hundreds of meters below the base. In such a situation, it is very difficult to cope with a glider since even in very tight spirals only 15 m/s are reached. The result is a real danger of life if one gets sucked into such a storm cloud. The pilot loses all sense of orientation, is lacking of oxygen and no longer controls his vehicle due to strong turbulence and hail.



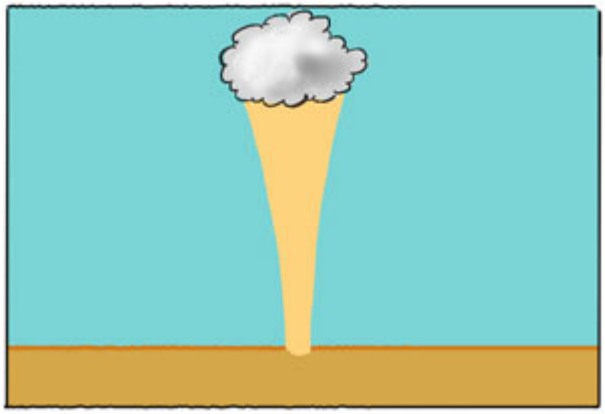


Links with practice: Caution and suspicion are needed when:
- the ascent rate under the cloud exceeds 5 m/s,
- the ascent area is wide and calm under the cloud, it can mean very high aspirations,
- the cloud is dark, convex in the middle with curved edges.

One should know that when getting away from the cloud, one is still rising for some time.
This is the reason why a straight flight in a 5 m/s ascent gives a flight line of 30° up.
One should not go up till the cloud base but move away from it considering its size.

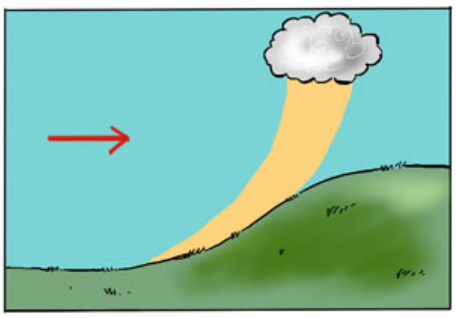


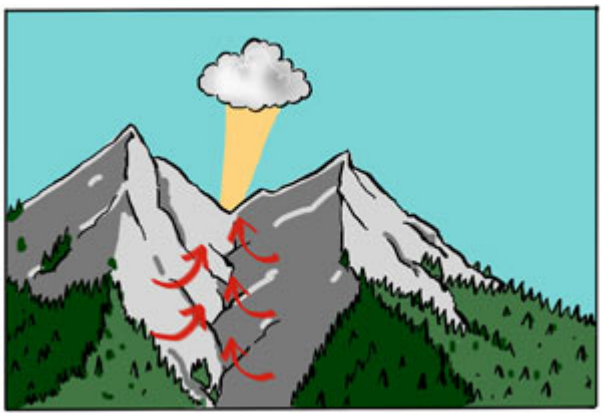
4.4.4 Thermal detachment



Without wind, a thermal bubble can develop peacefully.
After enough warming it separates from the ground and rises vertically.

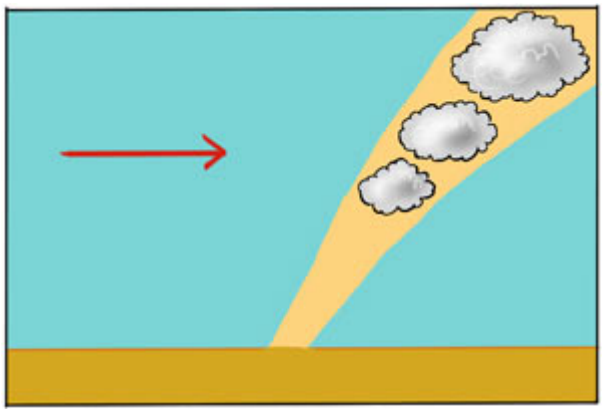
The bubble detachment is due among others to:
- tremor (eg. flying objects landing)
- temperature variations between different soil textures (eg. cloud shadows on the ground, forests, snow-ground boundaries, lakes, roads, etc ...)

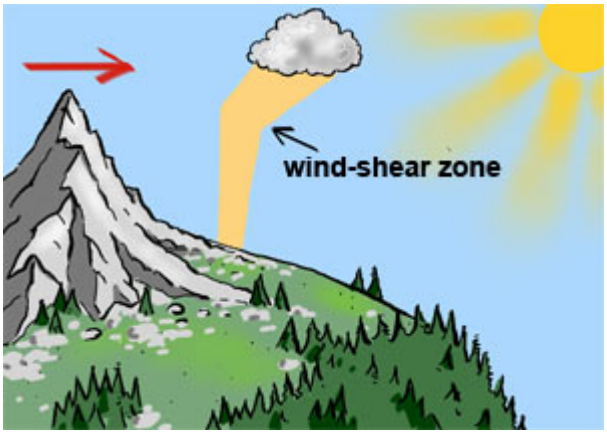




If the wind is low thermal bubbles leave the ground and go up near the place of origin.
The best locations for these separations are:
• forest edges respectively vegetation changes,
• change in the country profile,
• slits in the mountain slopes and on ridges in general.

Strong wind takes the thermal off the ground before it is sufficiently developed.
This creates a chopped up thermal, broken, difficult to use.

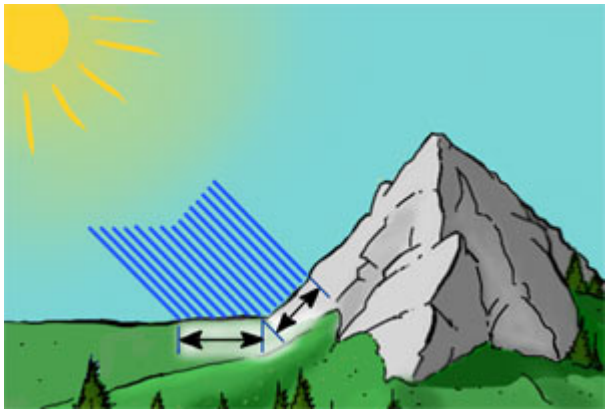


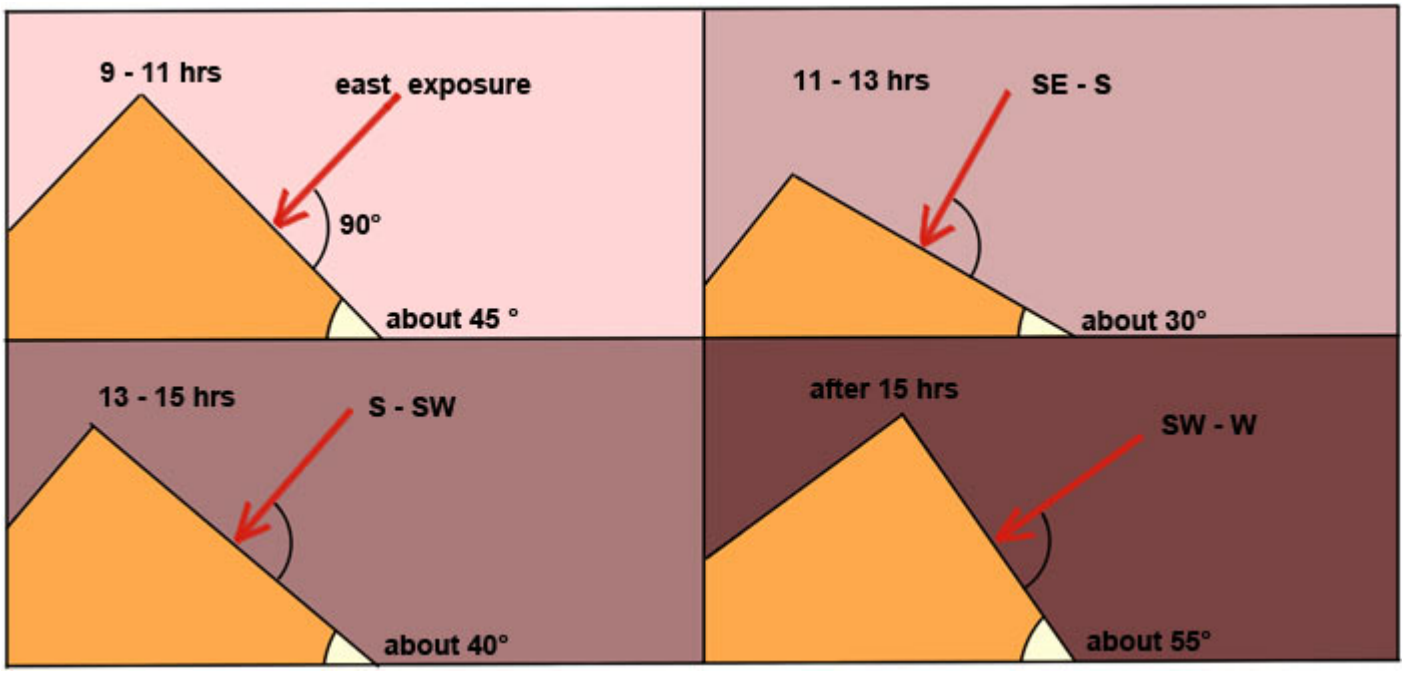


Good thermals develop in places sheltered from the wind.
Thus the right places for taking off will always be downwind on the edge of forests, buildings, hills, mountains, etc...
Warning : If one exploits the thermal downwind, one can spiral till the boundary between the upward thermal and the prevailing altitude wind. This contact zone is turbulent and is called **wind-shear zone** .

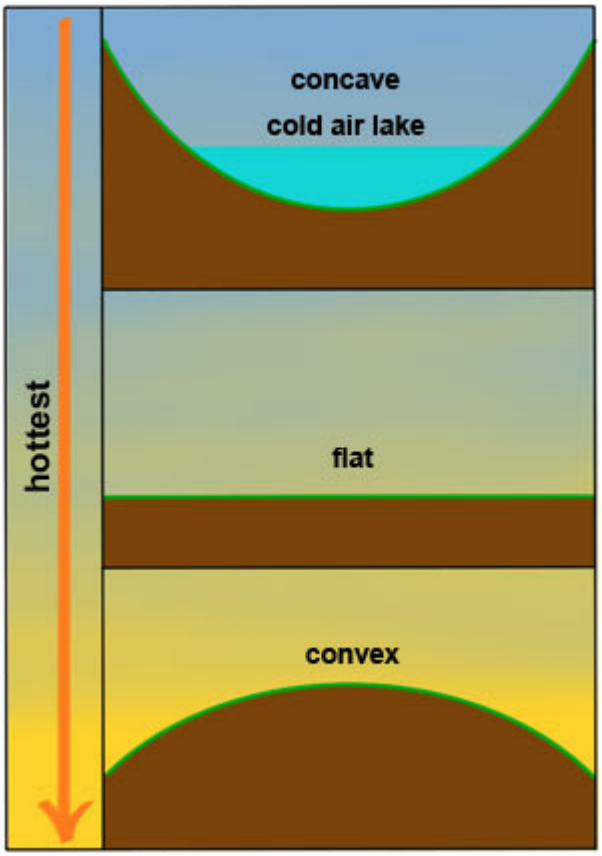
4.4.5 Factors influencing the thermal

• **Inclination of the slope, aspect and position of the sun**:
Surfaces perpendicularly touched by sun's rays get the maximum solar energy. Regarding the slopes, the south-facing slope (sunny slope of a mountain) inclined at 45° does not get more than 70% of this maximum energy while the north-facing slope (mountain side exposed to North, ie. to shadows) gets only a scattered energy. On an annual average the South Southwest slopes are the sunniest and warmest. Compared with a North slope, a eastern slope is 20% warmer, a western slope 30% and a southern slope 40% warmer.





• **Orography**:
The concave surfaces such as valleys are, at an annual average, 20% cooler than plains.
Convex shapes such as ridges or domes are 10% warmer.
The main reasons for these differences are:
•
- The fact that there is more shade in concave than in convex shapes.
- The fact that the cold air flowing overnight in valleys and hollows stays on the ground and creates a temperature inversion. This inversion must first of all be dissipated by the first sun's rays before it allows the start of thermal activity.
Normally inversions get dissipated in the late morning. After clear nights, if one wants to do thermal flight it is better to fly in the second half of the day.



- **Soil texture** (soil type).
  - **Absorption and reflection**:
    A portion of the solar rays is directly returned to space by the atmosphere and the Earth's surface. The remaining part is absorbed and converted into heat. The greater the possibility of absorption of this energy by the soil, the better will be the basic conditions for thermal release.

Absorptive capacity of some textures of soil types	
Wheat fields high and dry	95%
Asphalt	92%
Black soil, coniferous forests	90%

Absorptive capacity of some textures of soil types	
Land without vegetation, grass, deciduous snowy forest	85%
Wheat fields	80%
Sand	70%
Snow	30%

Basic rules: The shadier and darker the exposed surface to sunlight, the greater its absorption capacity will be. The clearer and smoother the exposed surface to sunlight, the lower its absorption capacity will be.

- **Heat conductivity and heat retention capacity**:
  Soils with a high conductivity and heat retention capacity will warm up slowly but they also render slowly the stored heat, ie long after the end of sunshine. Conversely, a low conductivity and heat absorption capacity means that the surface warms up quickly by sun radiation and cools down quickly, too.

Thermal inertia of different textures of soil types	
Arable and dry soils	0 - 15 min.
Concrete, asphalt, houses, etc ...	1 - 2 hrs.
Scree, rocks	11.5 - 21.5 hrs.
Low vegetation	2 3 hrs.

- **Comparison of thermal capacity air - water**:

Conduction	Water	Air
	very good	bad

The following correlation was obtained:

Water capacity in the soil	Air capacity in the soil	Heating of soil surface
low	high	strong
high	low	low

This explains the absence of thermal activity in a day of fine weather, when there was more than 5 l of precipitation per m2 the previous day.
As water has a great capacity to retain the heat, large surfaces of water such as lakes and oceans get this heat very slowly and keep it for a very long time. This is evident in autumn, when the land surface cools down strongly and it is possible to find weak upward surfaces over large areas above the relatively warm lakes. But generally, there is almost no thermal on water. The amount of water contained in vegetation varies greatly, the more it is green, the more it contains. A recently cut meadow, for instance, is not conducive to thermals while the same field, the next day, with a dry and isolating hay layer can become a real thermal oven.

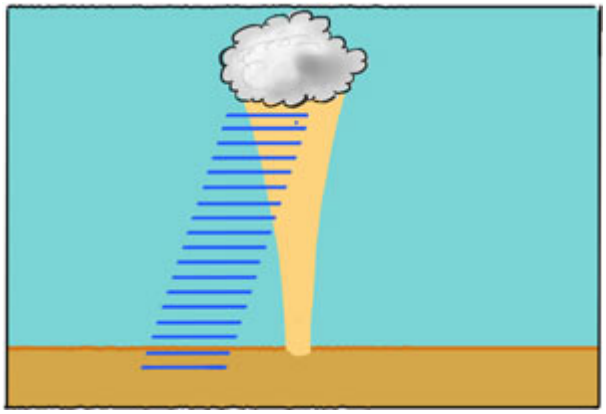
Summary of thermal properties of different soils.
The best surfaces for thermal flight are at the top of the table and the less usable are at the bottom.

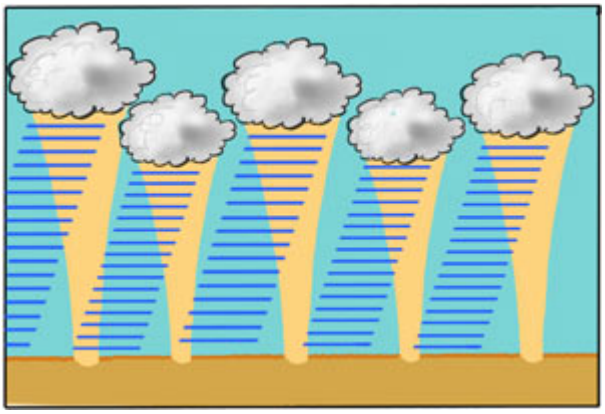
Soil texture	Properties	Warming	Inertia	Features
Asphalt Concrete Pebbles Rocks	+ dry + good absorption - relatively good conduction	good slow	1 - 2 hrs.	long and continuous thermal
Dustwallow drained	+ presence of air in the soil + good absorption	very good fast	short	
Farmland	+ presence of air in the soil + good absorption	good fast	short	the closer we get to the product maturing planted, the more thermal will be good

Soil texture	Properties	Warming	Inertia	Features
Grasslands	+ mown - unmown + lean - greasy	very different		hay is excellent when dry and ventilated
Bushes Heath	+ ventilated	moderately good delayed	2 - 3 hrs.	
Coniferous forest	+ cleared and dry soil	moderately good delayed	2 - 3 hrs.	in winter, no snow and bare branches can provide thermal
Deciduous forest	- high evaporation - shading	bad		
Wet marshes	- high evaporation	bad		
Snow and glaciers	- important reflection - cold	none		
Water	- high conduction	very slow		

The constant search for suitable thermal flight surfaces according to the table above is the key to long flights especially in the lowlands. If flying in mountain it is the constant search for a suitable topography and land exposure to sunlight that allows long-distance flights.

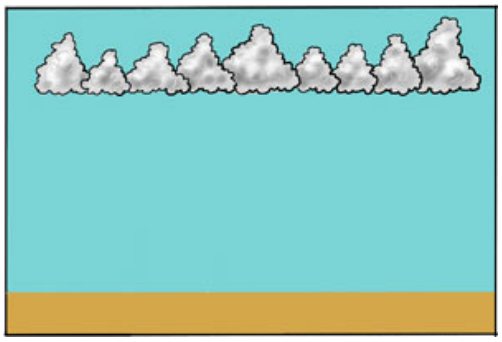
• **Cloud coverage**:
When we want to determine the amount of clouds in the sky, the sky is divided into octars (eight equal parts) and then the number of octars occupied by clouds on the observation site is registered. These details are useful because cloud shadows on the ground reduce the thermal activity.

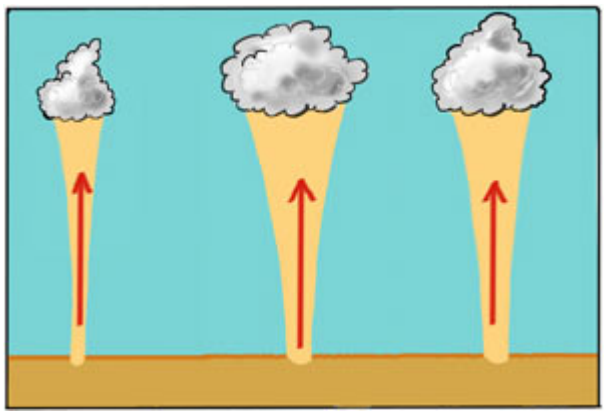




If the sky is covered over its half (5/8), the thermal is almost blocked. In addition, dust and smog adversely affect the formation of thermals.

Cloud streets are an exception as they are very stable ascending zones and are thermally efficient even if clouds obstruct 5/8 of the sky.





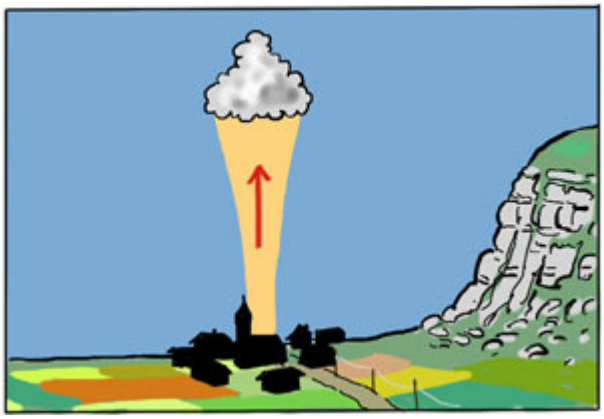
A cumulus layer blocking 1/8 to 3/8 of the sky is ideal.
In this case almost all the clouds are indicators of exploitable upward movements.

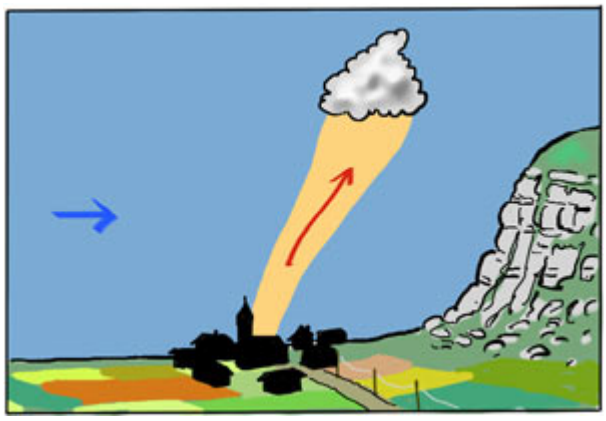
Solar rays are attenuated by:			
Cirrus	10 - 15 %	**Altostratus**	40 - 60 %
Cirrostratus	20 - 25 %	**Fog**	80 % +

Cirrus and cirrostratus weaken the thermal development and altostratus suppress them almost completely.

Links with practice:
If the clouds cover the sun for a short while, it is best to fly on surfaces with high heat conductivity since they will dissipate their stored heat.

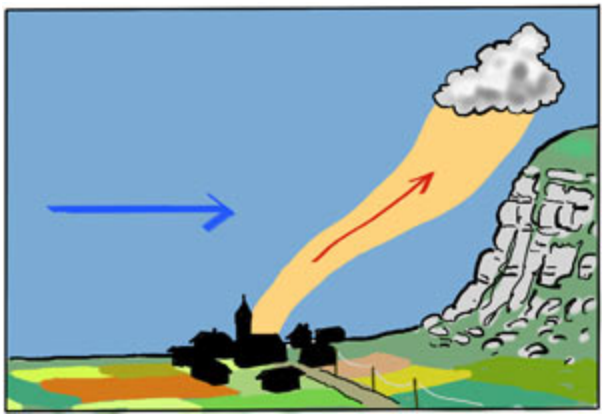
• **Wind**:
In still air, the heat source lies vertically to the cloud.
The air rises vertically. It is therefore preferable to spiral in the thermal by making regular circles.
In this case the best upward rate is in the centre under the cloud.





In the presence of wind, the thermal column bends.
If the wind is too strong it can break it.
Good thermals can only develop if the wind gradient is less than 3 km/h per 100 m altitude.

If the wind gradient increases continuously, the thermal column is located upwind in relation to the cloud.

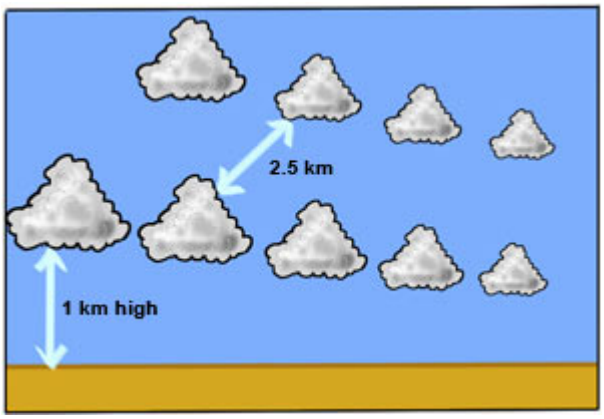


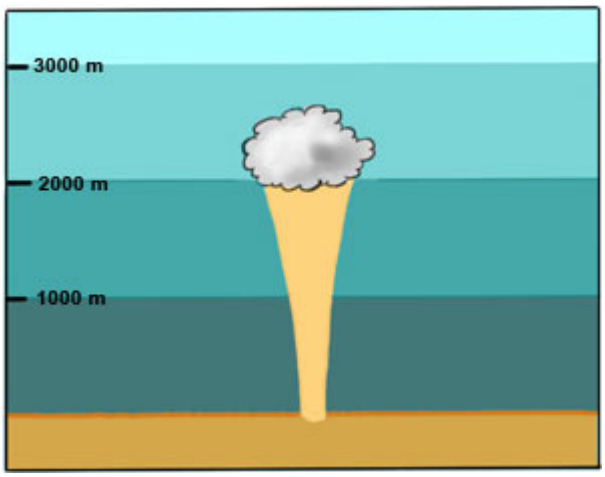
Links with practice:

By north wind thermals can be found on the northern slopes.

They are taken by the wind, as is the case in the Pre Alps where, on north wind situation, there are often excellent thermal flight conditions.

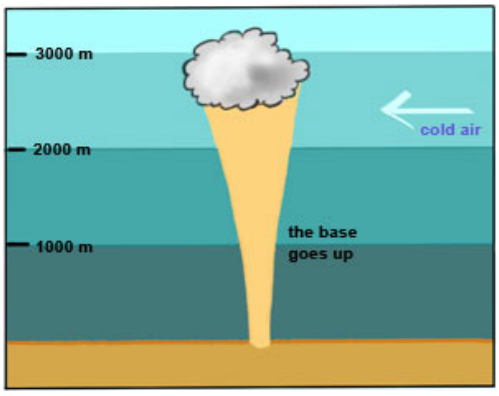
Cloud or thermal streets form if near the ground a light wind with a good gradient (increasing the speed with altitude) is blowing under an inversion layer.
The distance between the cloud streets is 2 times ½ the height of their base.
In between two of them there are downdrafts.

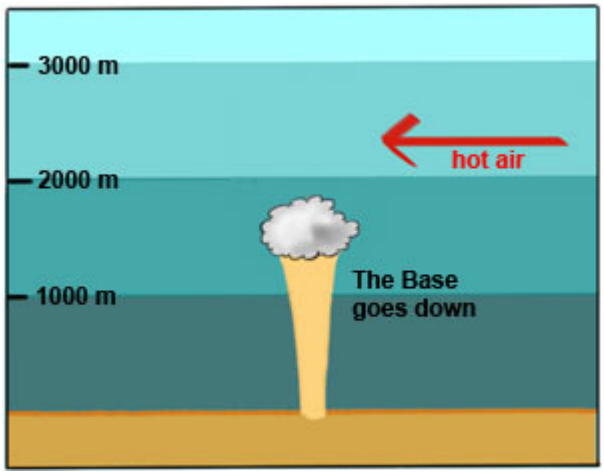




• **Advection**:
A horizontal air supply with a different temperature influences the thermal duration and strength.

A supply of cold air aloft (recognizable by the upper winds rotation to the left) in the convective system, strengthens and lengthens the thermal.

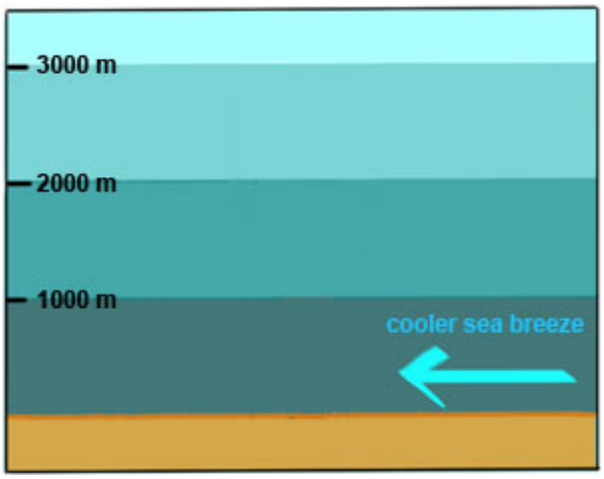




In reverse order, a supply of warm air aloft (recognizable by the upper winds rotation to the right) coming from South-West, weakens the thermal because the advantage in temperature of an air bubble rising weakens faster in the warm air arriving. It follows that:

• the thermal weakens its intensity,
• the thermal rises lower,
• the thermal stops faster.

The supply of cold air near the ground reduces greatly the thermal activities.
Sea and large lakes have a stabilizing influence on their immediate environment, which has a negative effect on thermal activity.
The warm air supply near the ground is almost inexistent.



4.4.6 Duration of thermal

- **Start of the thermal**:
  In the mountains just after sunrise, the first upward winds occur on steep slopes facing east. But for a flight in thermal conditions to be possible, one must still wait 2 to 3 hours. In valleys and plains one must wait at least 5 hours because the barrier inversion due to clear nights must be previously dissolved. If the thermal starts early in the morning at the beginning of a high pressure, it will begin each day a little later because of the change in the air mass.
- **End of the thermal**:
  In the mountains, always on steep slopes facing west, the thermal can last, possibly with a supply of cold air aloft, until sunset. The latter usually stops one or two hours before sunset. As a rule: the later the thermal starts, the sooner it stops in the evening.

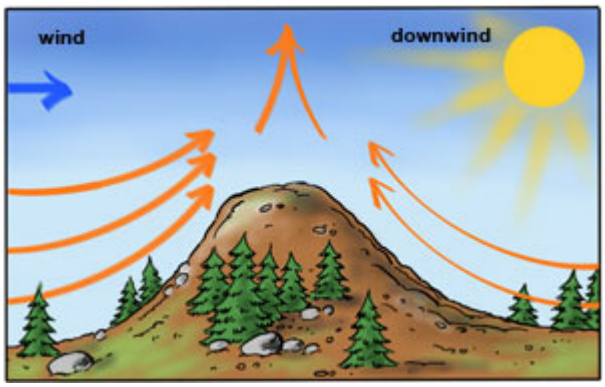
The thermal is hindered by:

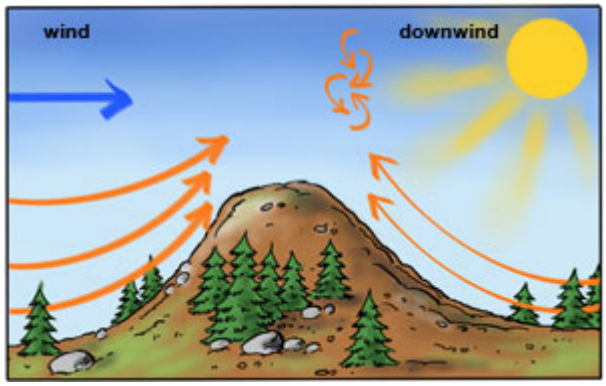
- a supply of cold air near the ground,
- a supply of warm air aloft, for example a warm front arriving,
- a strong wind,
- shading by the presence of clouds in formation.

Links with practice:
If the upward wind is stopped by shade, it’s worth waiting to take off when radiation is active again and new upward winds occur.

4.4.7 Lee thermal

In a general situation when a low pressure wind is blowing, one can thermalling downwind in good updrafts without any downwashes or rotors.





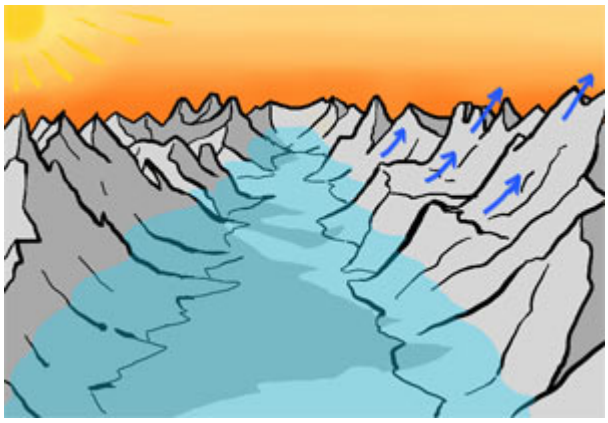
On the contrary, if the wind is strong, wind-shears appear in the border zone between the pressure wind and the upward wind.

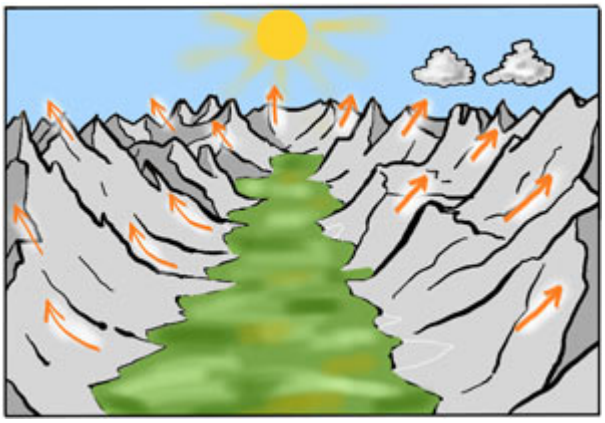
Links with practice:

Caution: If the downwind thermal is stopped because of insufficient radiation, one must wait that rotors and downdrafts invade the leeward side.

4.4.8 Thermal organization by local winds

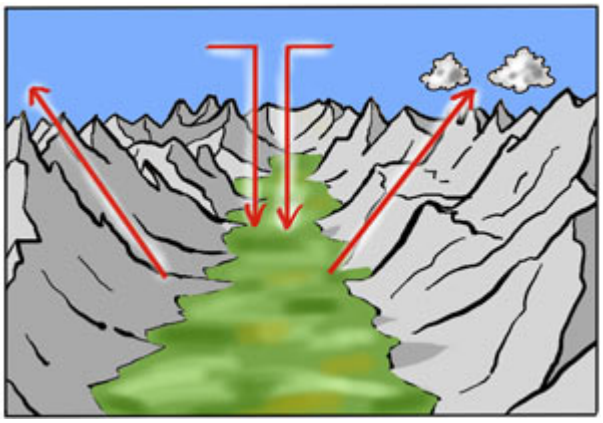
• **Valley winds and mountain winds**:
In summer, the upper eastern slopes warm up early in the morning, the ground being often dry, devoid of forest and the angle of incidence of sun's rays perpendicular to the slope.
So the air near the slopes warms up, expands and begins to climb.

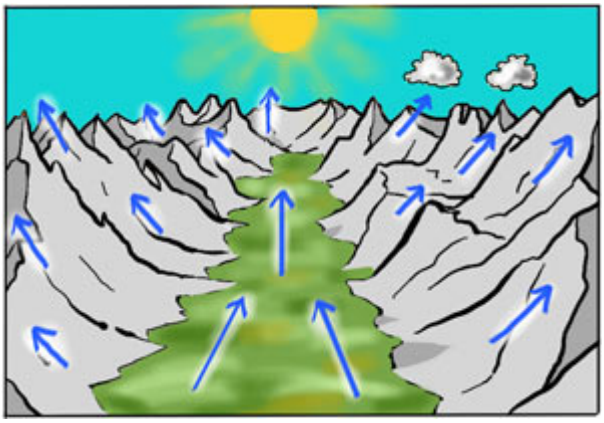




Around noon, all the valley slopes are warmed by the sun that reached its zenith.
At the same time cold air lakes that were formed overnight completely disappeared by this time. Upward thermal winds are now blowing on all slopes except on the northern faces.

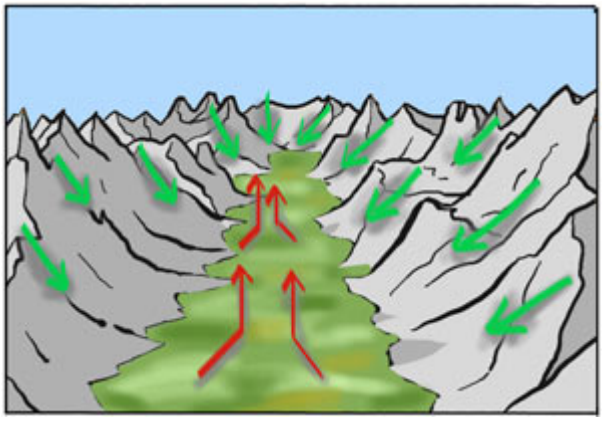
If the rising air masses cool down enough to reach the temperature of their dew point, small cumulus clouds will be formed over the peaks.
Above the middle of wide valleys air masses come down again to partially equalize the pressures.





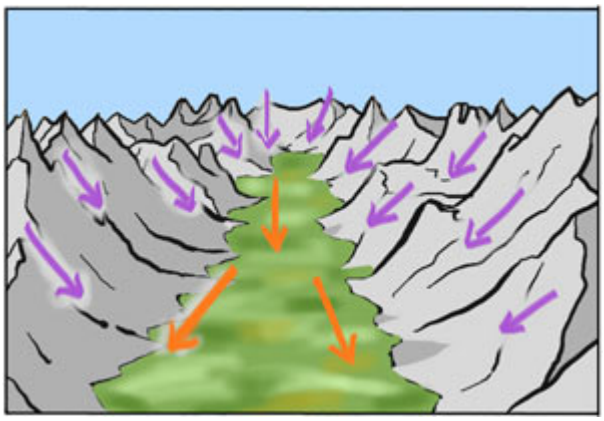
But as all slopes evacuate ascending air, the pressure equalizing is done by an input of air drawn into the Middle-Country in order to allow this continuous supply of thermals.
This creates the **valley wind**. This generally strong valley wind disturbs the formation of thermals in the centre of the valley which explains why thermals at the base of the valleys are always very short.

In the afternoon, the eastern slopes are the first to cool down then the southern ones and the western slopes in the evening.
The air near the ground colds down too.
Being heavier, it begins to flow along the slopes.
But this cold air coming down meets the warm air in the valley and it causes a thermal detachment (A) on the shaded side of the valley.

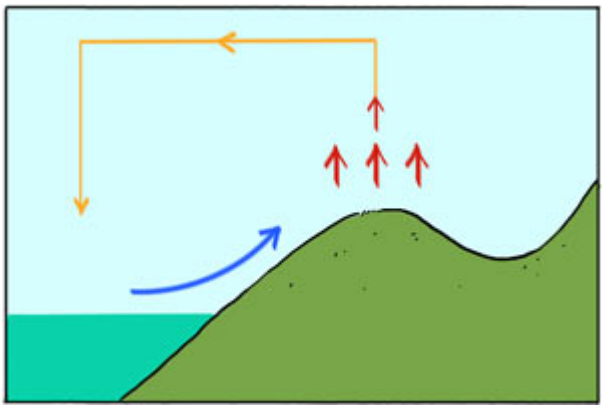


Since all slopes have downward wind, the system reverses and, for a fixed period of time, there are thermals in the centre of the valley which are called **inversion thermals** or sometimes evening thermals.
Links with practice:
When choosing the take off site one must take into account the orientation of the slopes that have more or less thermals depending on the time of the day.

Later in the evening, the valley bottom has cooled to the same temperature as the mountain slopes.
The evening thermal stops.
Then the air goes down overnight along the valley till the plain at 5 to 10 km/h, what is known as the **mountain wind**.

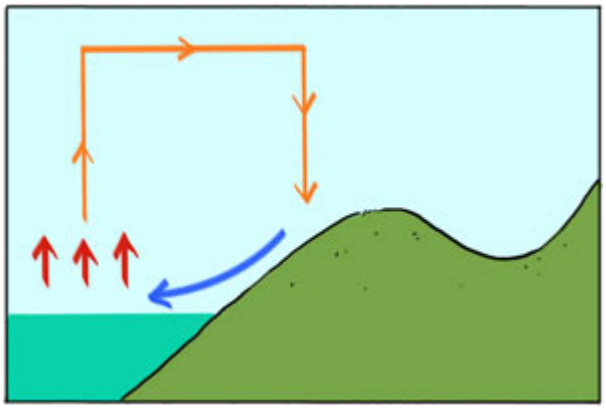


Land breeze and sea breeze (lake):



As we have seen repeatedly, with the first rays of the sun land surfaces warm up and the thermal is created.
The rising air masses must be replaced by fresh air.
This one comes from the sea or large lakes nearby.
This thermal compensation is called: sea breeze or lake breeze.
This wind blows till the evening when the land surface cools down.

But as these surfaces cool faster than the surrounding wet surfaces, the flow reverses and the air will rise above the water and the compensation will be done from the land.
At this moment we talk of **land breeze**.

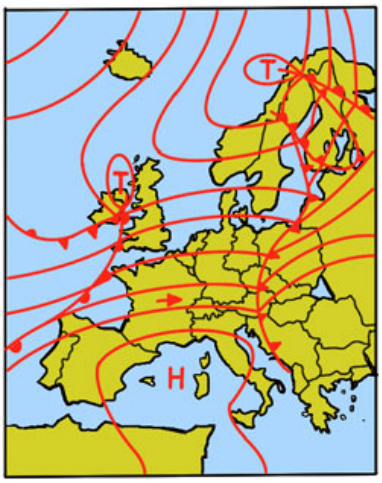


4.5 - Typical weather situations

Note: These weather conditions are given as an example for Switzerland.

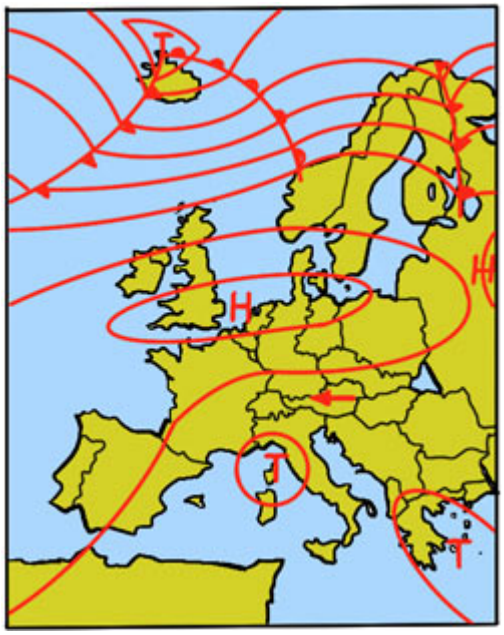
4.5.1 West situation

- **Occurrence**: very often, especially in spring and autumn.
- **Weather**: turbulent and unstable especially in the vicinity of cold fronts.
- **Wind**: caution during autumn storms; in the winter, gusts and shears in the vicinity of fronts.



4.5.2 East situation

• **Occurrence**: especially in summer and winter.
• **Weather**: in winter, altitude fog and in summer good weather without precipitation, up to 200 meters high haze often with less than 10 kilometres of visibility.
• **Wind**: from the North - Northeast dry, because of the canalization between the Jura and the Pre Alps the wind is stronger in the region of Lake Geneva.
Links with practice: excellent flying conditions, especially on exposed slopes of the Pre Alps.



4.5.3 Foehn situation

The foehn is a known and dangerous phenomenon to general aviation in the Alps.
• **Occurrence**: low pressure in the West and high pressure over the Gulf of Genoa
• **Weather**: fine north of the Alps and rainy to the south.
• **Wind: extremely strong gusts up to 130 km / h in the foehn valleys. Wind up to 180 km / h on the Alps ridge. Strong turbulence and powerful downdrafts.**

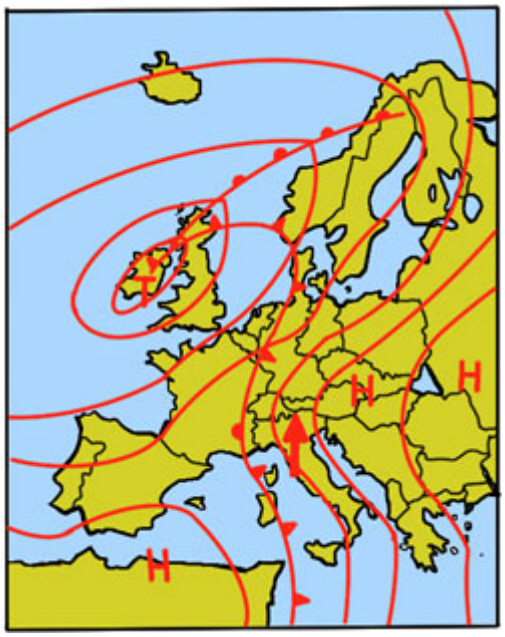


Photo 3-23: *Typical foehn clouds:* ***Lenticulars*** *(saucer shaped). These local clouds show that air masses are moving fast in altitude.*

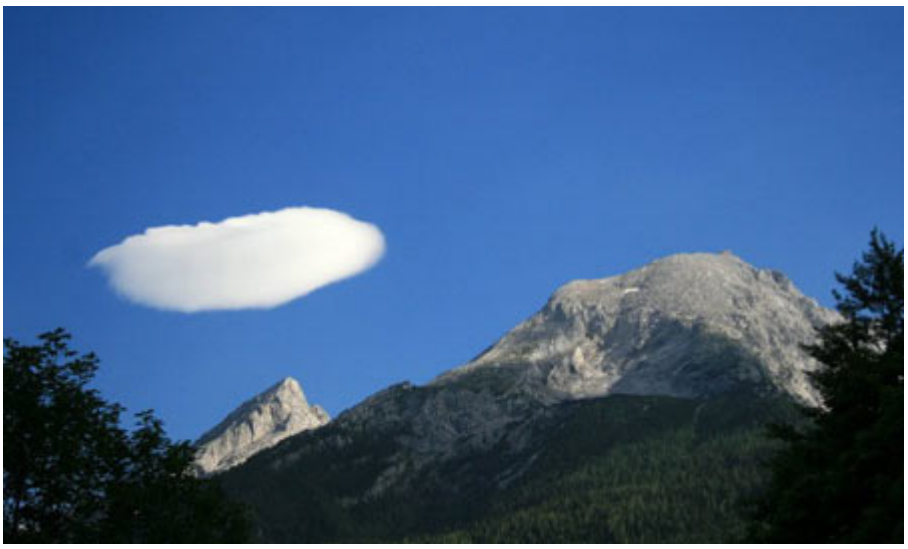
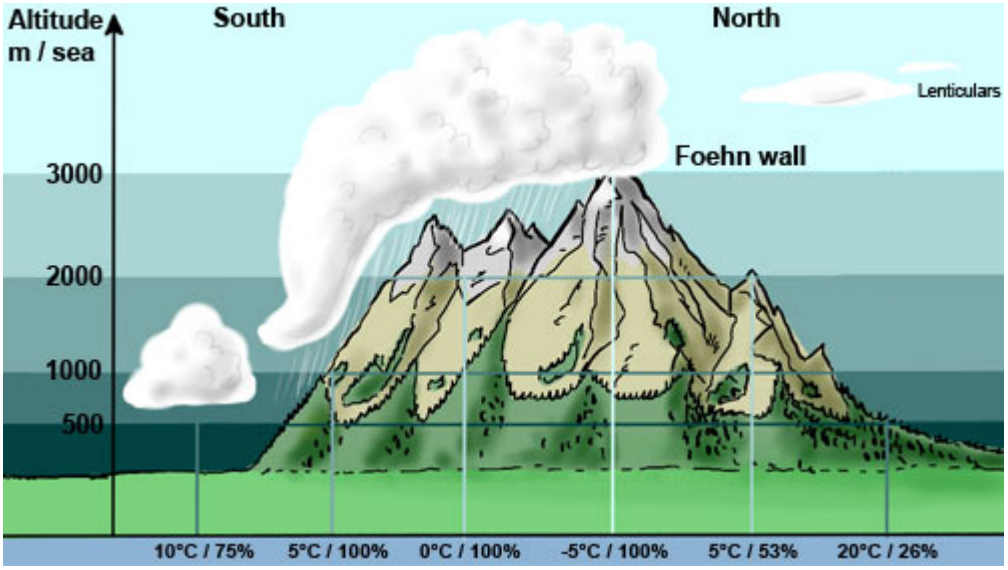


Photo 3-24: *Foehn wall*

Photo 3-25: *Hole Foehn, regime characterized by a band of blue sky and, downstream of the phenomenon of "blown" clouds resulting a strong wind. Photo wikipedia.*

- **Formation**: conditions for a situation of south foehn in the Alpine valleys.



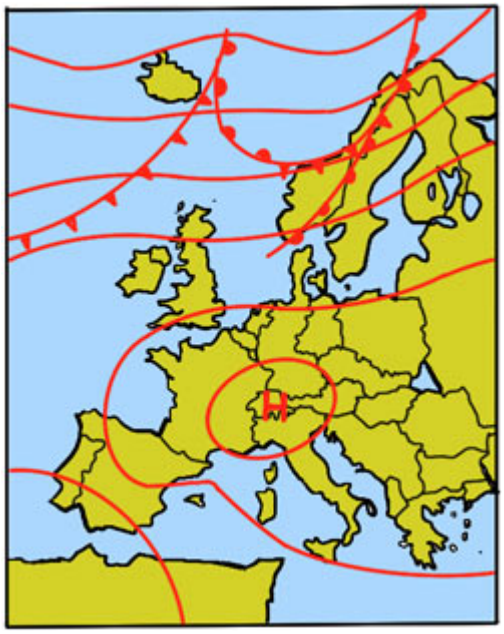
Switzerland is in a warm area and a cold front enters the Jura. Between North and South an important difference in pressure is created. Moist Mediterranean air glides on a lake of cold air south of the Alps and rises onto the Alps slopes cooling down according to the dry adiabatic lapse rate until it reaches its dew point. Clouds are formed and the air continues its ascent this time according to the saturated adiabatic lapse rate. There is heavy rain in the Southern Alps.

The air arriving at the Alps summit has lost its moisture and descends on the Northern flanks of the Alps ridge. There, it warms by compression according to the dry adiabatic lapse rate. So we have a warm dry wind that dissolves completely the clouds above the Pre Alps and the Middle-Country. That is what is commonly called the “foehn hole”. The resulting wind is the seat of important rotors, it is due to the accumulation of the large pressure difference between South and North (strong wind), the perpendicular hitting on the Alps chain (turbulent wind) and the canalization in the valleys (acceleration and deflection of winds that can hit at 180° at a valley confluence).

4.5.4 High pressure situation

• **Weather**: normally fine, often severe haze. Caution, from autumn to spring there is often fog till the ground with well defined upper limit in altitude. In summer, with the high pressure decrease, there are heat thunderstorms in high mountains.
• **Wind**: almost quiet.

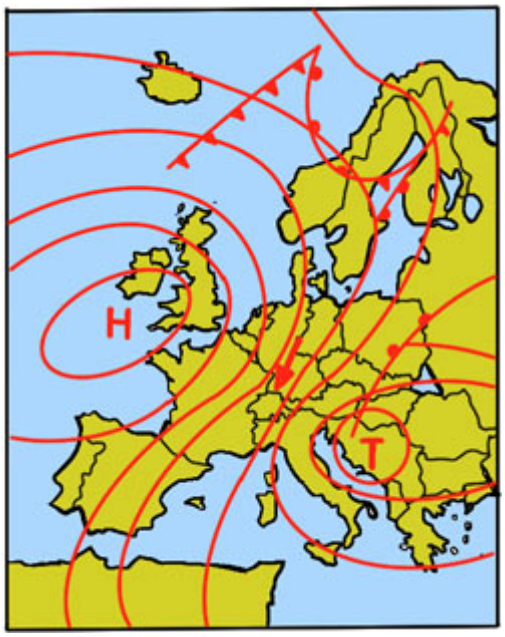
Links with practice : The beginning of a high pressure promotes the formation of thermal updrafts. The air masses that sink in the centre of high pressure (subsidence) get warm by compression in dry adiabatic. It follows that the higher the high pressure, the warmer will the lower layers be and therefore the worse will the thermal developments be.



4.5.5 Barrier situation

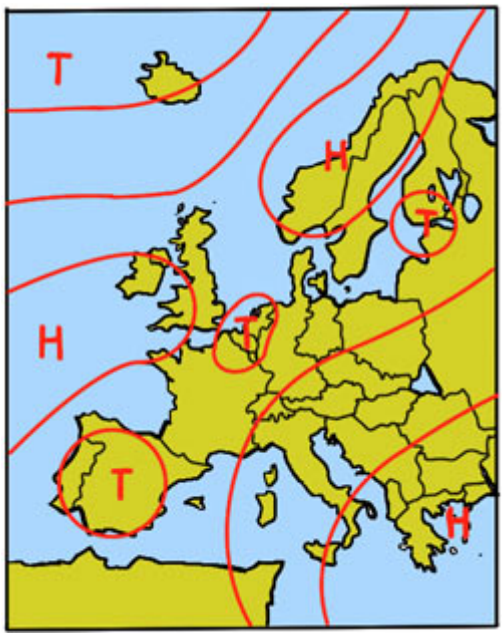
• **Weather**: very bad in the North with lots of rainfall.
• **Wind**: usually low to moderate.

Links with practice : in barrier situation north of the Alps, there is good weather in the South due to North foehn phenomenon. This situation is not conducive to paragliding because the wind is strong with turbulence.



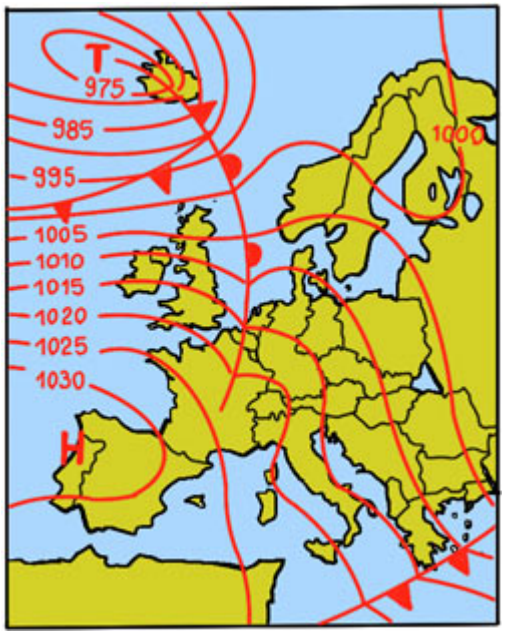
4.5.6 Low pressure situation

• **Weather**: bad over a large area with abundant and continuous rainfall.
• **Wind**: low.



4.5.7 Barometric marsh situation

• **Occurrence**: uniform distribution of pressure across all Europe, especially in summer.
• **Weather**: fine in the morning becoming stormy by noon. Risk of heat thunderstorms in the afternoon. Heat haze with upper layer from 3000 to 4000 meters.
• **Wind**: low except close to thunderstorms.



4.6 - Thunderstorms

• **Occurrence**: Uniform distribution of pressure over a large area, moist air mass with unstable layers of the atmosphere.

> **Links with practice**:
> **Caution**, thunderstorms can develop, respectively move very quickly. If, according to weather forecast, storms are expected, the greatest caution is needed in flight. Weather evolution should be continuously watched over.

• **Observations**:
  ◦ Before the storm: especially during the summer months, cumuliform developments can turn very quickly into cumulonimbus.
  ◦ At the start: **danger**, strong gusty winds, waterspouts, torrential rain, thunder and lightning, sometimes even hail.
• **Air mass thunderstorm**:
  ◦ Strong rising thermal winds can create an over development in the afternoon. Cumulus congestus become anvil-shaped cumulonimbus.
  ◦ Location on a specific place.
  ◦ Duration: 1 to 2 hours.
• **Orographic thunderstorm**:
  ◦ Air is forced up by the relief, if it arrives at the unstable and moist layers the air mass “hyper develops” and forms a cumulonimbus.
  ◦ Local situation.
• **Frontal thunderstorm**:
  ◦ A mass of cold air comes into contact with a warm air mass (cold front), like a lever this air mass raises the warm air, the latter ``hyper develops'' and forms a cumulonimbus.
  ◦ It spreads over several kilometres.
  ◦ Do not occur only in summer.

***Special feature*: this kind of storm can occur both day and night.**

For a CB to grow, warm and moist air must rise. When this mass of air reaches its dew point, a large amount of water vapor is condensed. The higher the temperature the larger can be the amount of moisture to condense and thus a very large quantity of energy will be released by this change of state. So that during its continuous rising, this air mass hardly cools down. If in addition this air evolves in an unstable atmosphere (large temperature gradient), the temperature difference in the cloud between the ascending air mass and the ambient air mass increases even more. This results in an over development of the cloud until the height of the tropopause which, by its temperature inversion, will stop this uncontrolled ascent that began at 500 meters, at about 10 to 12000 meters in altitude.

Photo 3-27: *Clouds in the form of small towers (* ***altocumulus castellanus*** *) are a sign of an emerging stormy conditions.*

Photo 3-28: *The first cumulus create later in the morning ...)* ***Cumulus humilis*** *).*

Photo 3-29: *... it grew gradually in altitude (* ***altocumulus mediocris*** *) ...*

Photo 3-30: *... and develop during the afternoon mighty clouds... (* ***Cumulus congestus*** *).*

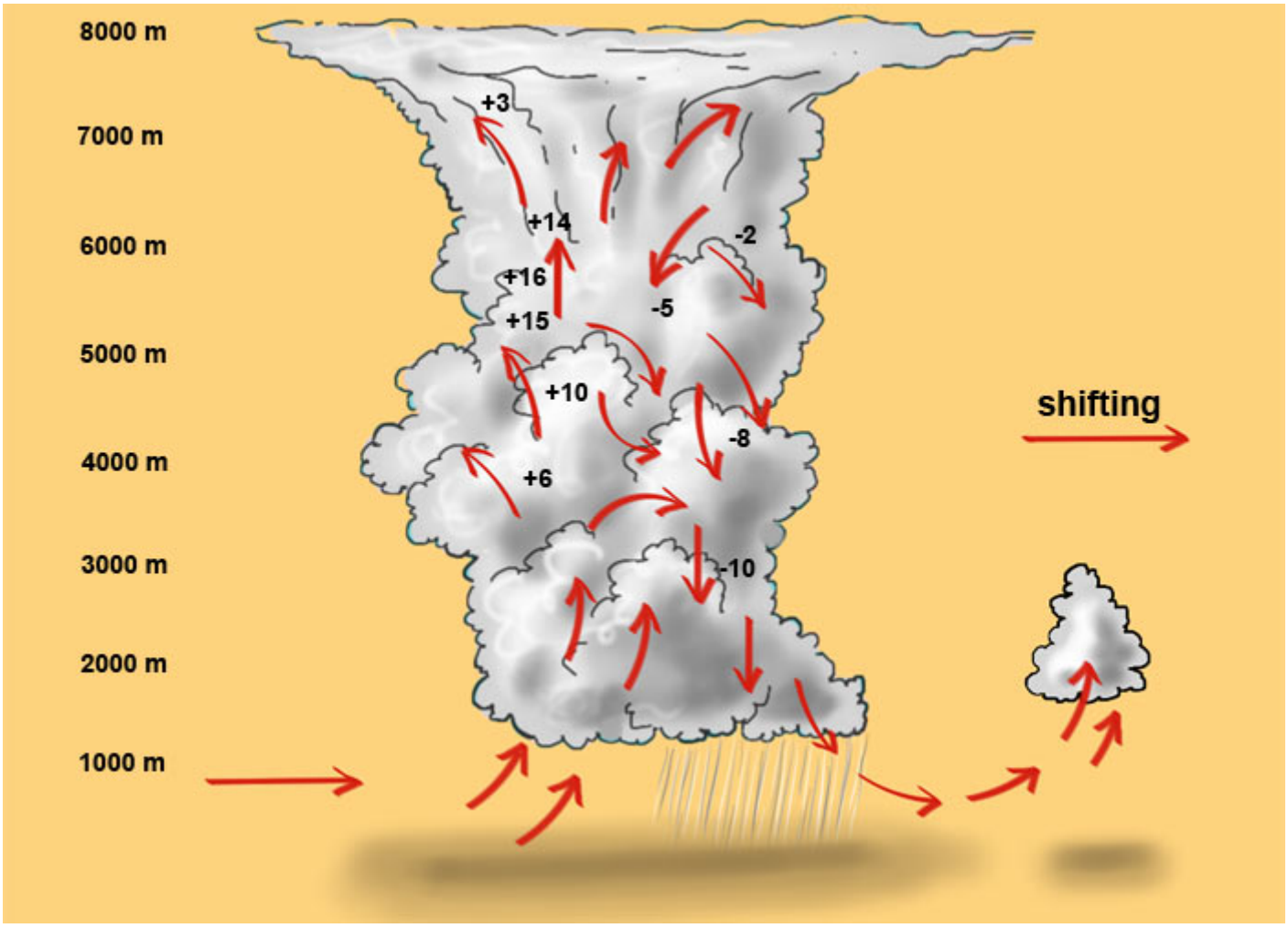
Photo 3-31: *With its frayed upper edges, cumulus congestus continues its metamorphosis into becoming a storm cloud (cumulonimbus calvus). In its final phase of development with its particular anvil shape (* ***cumulonimbus capillatus*** *) ...*

Links with practice:

Warning, the flight or suck in a CB represents a real danger of life by:

- the paragliding damage due to extreme turbulence,
- oxygen deficiency from 4500 meters,
- frostbite due to very low temperatures,
- physical injuries due to lightning and hail.

Wind flow within a cumulonimbus cloud. **Danger**: You have to beware of strong winds greatly descendants in the area of precipitation.



The figures indicate in m / s the rate of ascent **+** *or descent* **-** *of the air mass.*

4.7 - Weather information
WORLD WEATHER FORECAST SITES

- World Meterological Organization: world wide forecast information,
- World Forecast Report By BBC,
- Weather Offices by Country,
- DaylightMap: cloud layer live information,
- XC Skies: worldwide Specific Soaring Forecast,
- Météociel: European weather forecast in french,
- Previmétéo: great Website, weather report in Europe, country by country,
- Meteoblue: weather close to you.