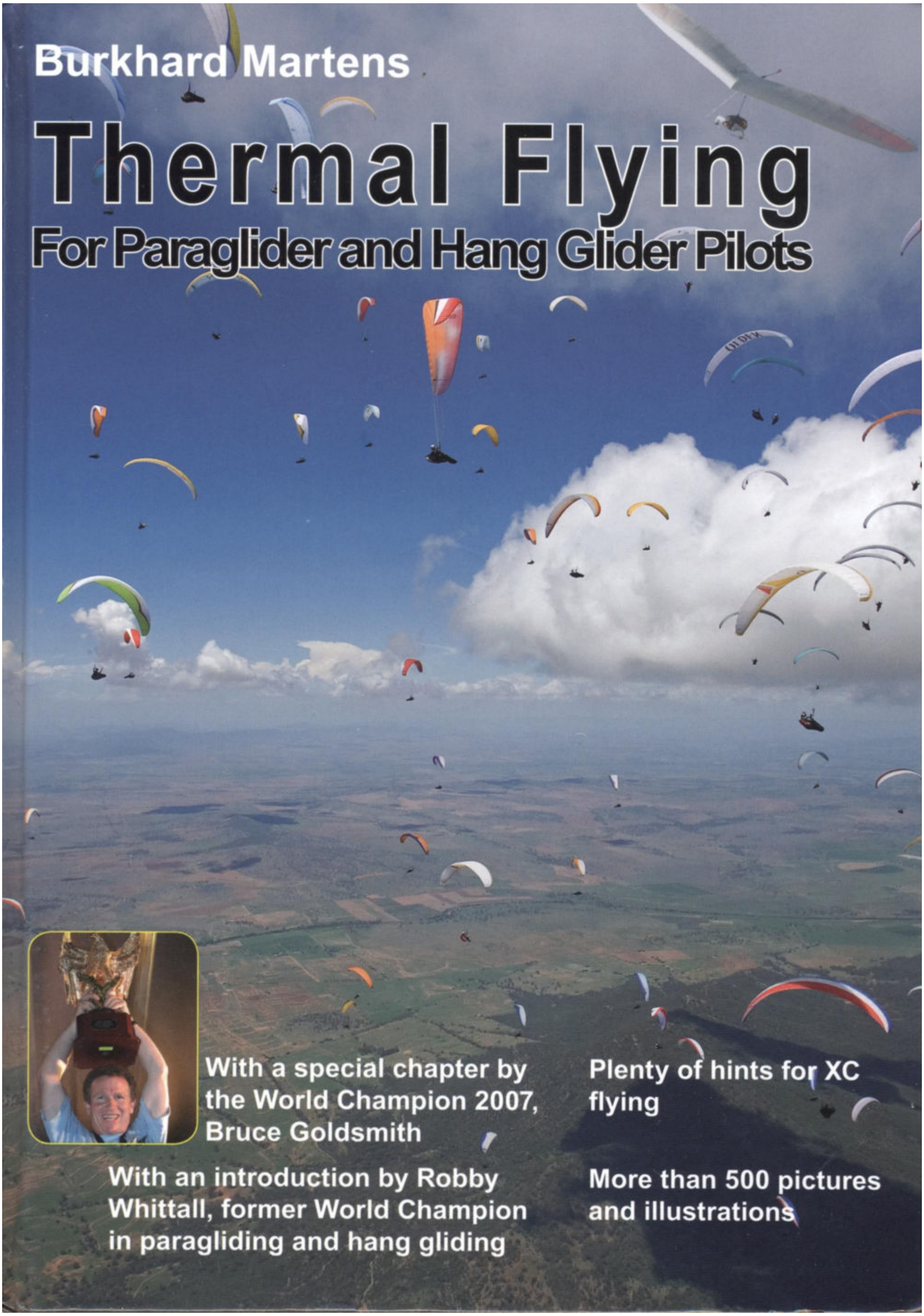

Burkhard Martens

Thermal Flying

For Paraglider and Hang Glider Pilots

With a special chapter by the World Champion 2007, Bruce Goldsmith

With an introduction by Robby Whittall, former World Champion in paragliding and hang gliding

Plenty of hints for XC flying

More than 500 pictures and illustrations

The book that really teaches you how to fly your paraglider or hang glider.

Thermal flying for beginners and pros.

Inside you will find comprehensive explanations to the following subjects:

- Thermal formation
- Thermal models
- Vortex ring structure
- Lift distribution in thermals
- Windward and lee thermals
- Release edges
- Clouds
- Centring of thermals
- Temperature gradients
- Soaring and valley winds
- Polars; how to measure them and how to use them
- XC tactics
- Bruce Goldsmiths' hints and tricks

The book is packed with little hints from the author, making it as good for casual browsing as for in-depth study.

Many photos and illustrations make the inaccessible accessible, and loosen the feel of the sometimes very information-laden pages. They further serve to induce reflection in the reader in an easy-to-grasp manner.

The bonus chapter by 2007 World Champion Bruce Goldsmith conveys the most important information for free flight in a condensed manner.

Burkard Martens was born in 1962 in Lower Saxony, Germany. After completing his studies in 1989 he moved to the south of Germany and took up paragliding. For several years he managed to work as an environmental engineer AND be a very passionate pilot, but from ‚94 his life has been inseparable from flying. From ‚94 to ‚97 he worked for paraglider manufacturers, and from ‚97 to 2003 he owned and ran a paragliding school.

Since ‚03 he has worked freelance as a instructor pilot, journalist and author. He took up hang gliding in 1998.

For 7 years Burkhard did the comp thing, flew in the German League, the Nationals and in the World Cup. He bagged several national and international records during this time, and some of them still stand.

Burkhards passion is the cross country flight, and after flying in the German XC League for ten years he finally managed to win the Sports Class in 2004.

This success was followed by the publication of the book „Das Thermikbuch für Gleitschirm- und Drachenflieger" in 2005. This book has already been translated to several languages.

In April 2007 the next book in the series, „Das Streckenflugbuch für Gleitschirm- und Drachenflieger" (The XC-Flying guide for paraglider and hang gliders) was published. Although it has only been on the market for a very short time the sales figures are already impressive."

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Pages 2/3: Panoramic flight above Tuxer glacier in Zillertal, Austria.
Pages 4/5: Launchinc from the Wallberg, Germany

Contents

Picture: Bruce Goldsmith

Introduction

„When the first version of‚Das Thermikbuch' was published back in May 2005 I really had no idea what to expect in terms of turnover. Since then the enthusiasm which has followed me in our small flying community has all but overwhelmed me, and even known pro's seem to have found useful parts in my book - check my Internet site www.thermikwolke.com for some of the comments I got.

The book was almost immediately translated to Russian, yet I couldn't find a publisher interested in marketing it in the much larger English/International market, let alone the French. I was told over and over that my name was not universally known and that the risk involved would be too great. However after yet more coaxing from friends and colleagues I finally decided to take on the job myself and publish the English version under my own banner.

My old World Cup friend Mads Syndergaard agreed to do the revision and translating, and Gerhard Peter did the final proof-reading.

In the two years passed since the first book was published I have received a great deal of feedback, much of which has been incorporated in the edition you hold in your hands. Some themes have been revised, some have been left out and a few new ones have been added. This means that the current English version is actually more up-to-date than the German one, as the 2. German edition is planned for 2008.

Mads has not just translated the book but also in fact done a complete revision of it, with numerous changes and additions. To watch this process from the sideline has been a great pleasure and I feel that we have got a good product on our hands.

In the autumn of 2006 I contacted Bruce Goldsmith to ask him if he would write a preface for the book. He suggested making more than that and actually added a chapter of his own. I feel that this has enriched the book immensely, and the fact that Bruce became World Champion in the mean time has pleased me immensely!

I'd like to thank Volker Schwaniz, who has been a valuable advisor in all meteorological matters. I also owe Volker a great big Jhank you" for the paragraphs that were exclusively written by him.

Another one who deserves my profound gratitude is my wife Nina-Renate Brummer. She has been patient beyond the call of duty, and she has been a valuable co-worker both as a photographer and as a motivator during the countless hours I have spent in front of the computer.

I wish you a lot of pleasure with the book, both when reading and when transferring the knowledge into the air. May your own thermal flights be benign, and may „Thermal Flying" help you to get more out of them!

Burkhard (Burki) Martens

Preface by Robby Whittall

In my humble opinion no matter how much you think you might know about flying you will never know enough... I have now been flying for over twenty years and I have amassed thousands of hours in the air but I am well aware that I am still learning and need to learn in the future.

We often overlook the importance of continuing our flying education and understanding once we reach a level that we feel is acceptable. For your own safety it is important to remain humble and realize that there is more to know about flying and the weather than you will ever be able to absorb. No matter what we must continue to strive becoming better pilots with better understanding.

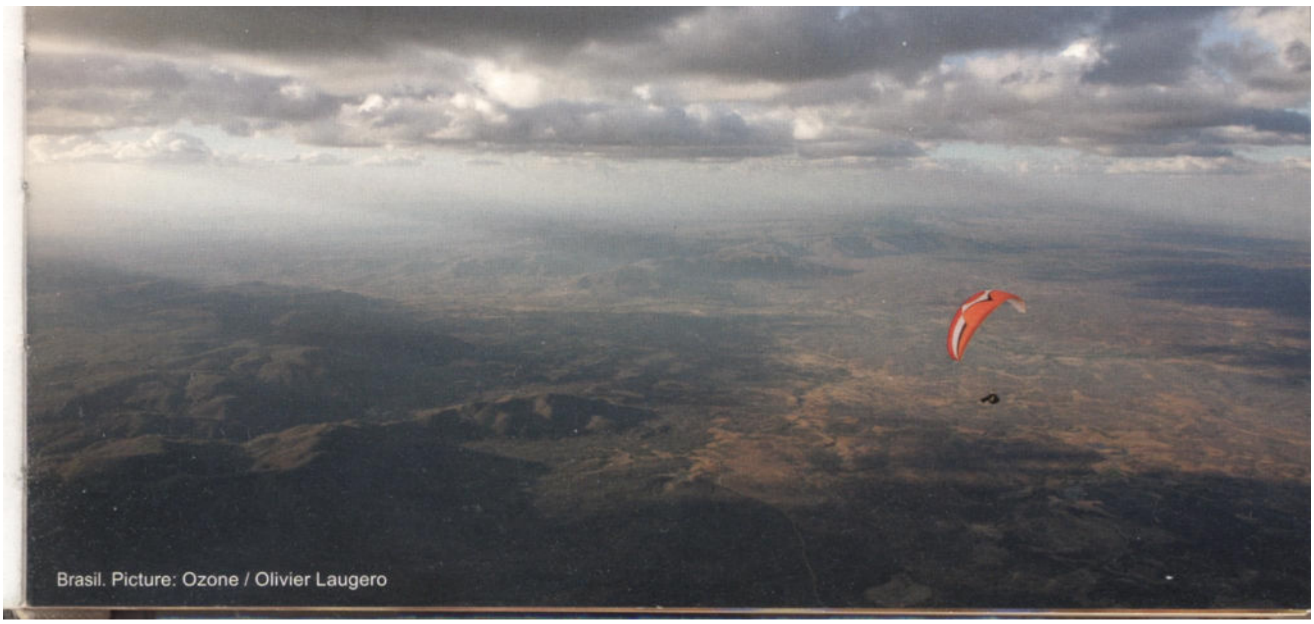
I was honored that Burki asked me to write a preface for his book. However to do so honestly I had to read it and in doing so I have increased my own understanding of flying and the weather. Within the pages of this book you will find great wisdom no matter what level of pilot you are. This book is full of excellent information from start to finish and it is accompanied by easily understandable diagrams and graphical depictions that help you to visualize many of the descriptions.

Please remember that you and only you are responsible for your own safety each and every time you fly. Use this book and the knowledge contained within to increase your understanding and thus your own safety.

Flying is a very beautiful thing, it can take you to heights that you never thought possible. It can change your life for the better, it can fulfill your soul and mind but it always has to be taken seriously. Educate yourself to continue the enjoyment and serenity safely.

Rob Whittall

Former World Champion in paragliding and hang gliding.



Brasil. Picture: Ozone / Olivier Laugero

Preface by Bruce Goldsmith

Thermals are like waves in the sky. They have huge force and power and riding thermals can be as exciting as riding huge waves in surfing. I have been hooked on thermal flying for 25 years now, first on hang gliders and now on paragliders. The thrill of finding invisible thermals and then climbing in them to fly XC is as precious an experience now as it was when I first started out flying. Playing with these powerful yet invisible forces of nature is an experience ownly shared by us and beautiful soaring birds.

When Burki first asked me to write a preface for this book, I was so impressed by the depth and detail in the book that I wanted to contribute my own chapter. This book will help pilots to learn more quickly and safely the art of thermal flying and will help pilots to learn quickly many of the techniques that took me years to master.

Bruce Goldsmith

World Paraglding Champion 2007

Bruce flying in Cusco, Peru. Photo Olivier Laugero

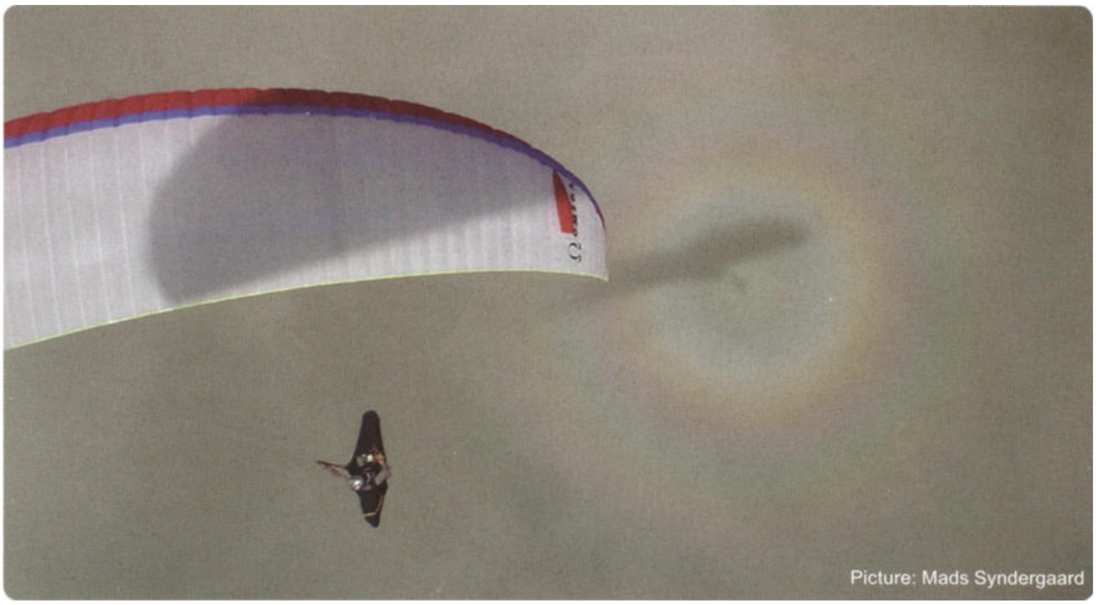
Preface by Mads Syndergaard

About the translator

Mads Syndergaard was born in Denmark in 1968. He discovered paragliding in 1987, after having had vivid flying dreams since childhood. Since then he has accumulated countless hours in the air, flying on the international competition circuit almost full time from 1994 till 2001.
Today flying remains his number one passion, although his young family does come a close 2nd...

This book was originally written especially for pilots flying primarily in the German, Austrian and Italian Alps. We felt however that most of the wisdom therein could easily be transferred to any mountain region, and during the translation I have strived to minimise the local bias of the text, just as I have edited content in places where I deemed it necessary. When reading you will still come across sections where the local Alpine bias is clear to see, we hope that the universal usefulness will still be apparent in spite of this.
As in the original version I have used he and him when I have spoken of the pilot. I hope our readers do not interpret this as sexism - it is done for purely practical reasons.
Enjoy the reading, be careful up there and don't blame us if your passion for paragliding grows to unexpected and impractical levels.

Mads Syndergaard



Picture: Mads Syndergaard

Welcome to the world of thermal flying

I was hooked on paragliding from the first flight, many years ago. Right from the first little hop into the air I knew that this was "it" for me. In the following years I flew as much as I possibly could as a full-time employed engineer - which was far too little for my taste. My idols were the club colleagues who had already been flying for two long years - I felt like they were untouchable in their skills.

To improve as quickly as possible I read everything I could lay my hands on, every book and every magazine. Manfred Kreipl's "Das Thermikhandbuch", although hard to read, became my most trusted friend. The book had no pictures and only a few drawings, and I had to read many passages over and over to understand everything.

I also read all the theoretical material that we were issued for our exams. Most of this was fortunately much easier to read. My favourite texts concerned the practicalities of flying; thermals, weather, trigger points, centring technique, valley winds (wind systems) - I devoured it all. Things like aviation law, navigation, aerodynamics and equipment knowledge also had to be learned for the test, but my heart was with the other subjects.

I wrote this book for all the pilots out there who feel just like I felt back then. It is about all the things that I, and many of my fellow students, found so intriguing when we first entered this wonderful world of free flying.

Picture 0.1 Panoramic flight above the Aletsch glacier in Valais, Switzerland.

If something like this book had been available back then I truly think I could have sold a copy to each and every student in the class. But there are so many little hints and tricks in it that even old thermal hogs should be able to find some nuggets here and there.

What really caught me about flying is the playing in and with nature. We have all learned through our flying education how warm air will eventually rise as a thermal, but to actually find this rising air and use it to go right up to cloud base is simply addictive. To combine more thermals in one flight, to fly to the next expected trigger point and actually find lift, then use this lift to go further still; this is in my mind truly awe-inspiring. Whenever this happens, when my theories prove themselves in real life I feel particularly alive and fortunate. So gliding towards a specific point on a hill and actually finding lift there is exhilarating every time. What it does for me is to prove that my understanding of nature is continually improving.

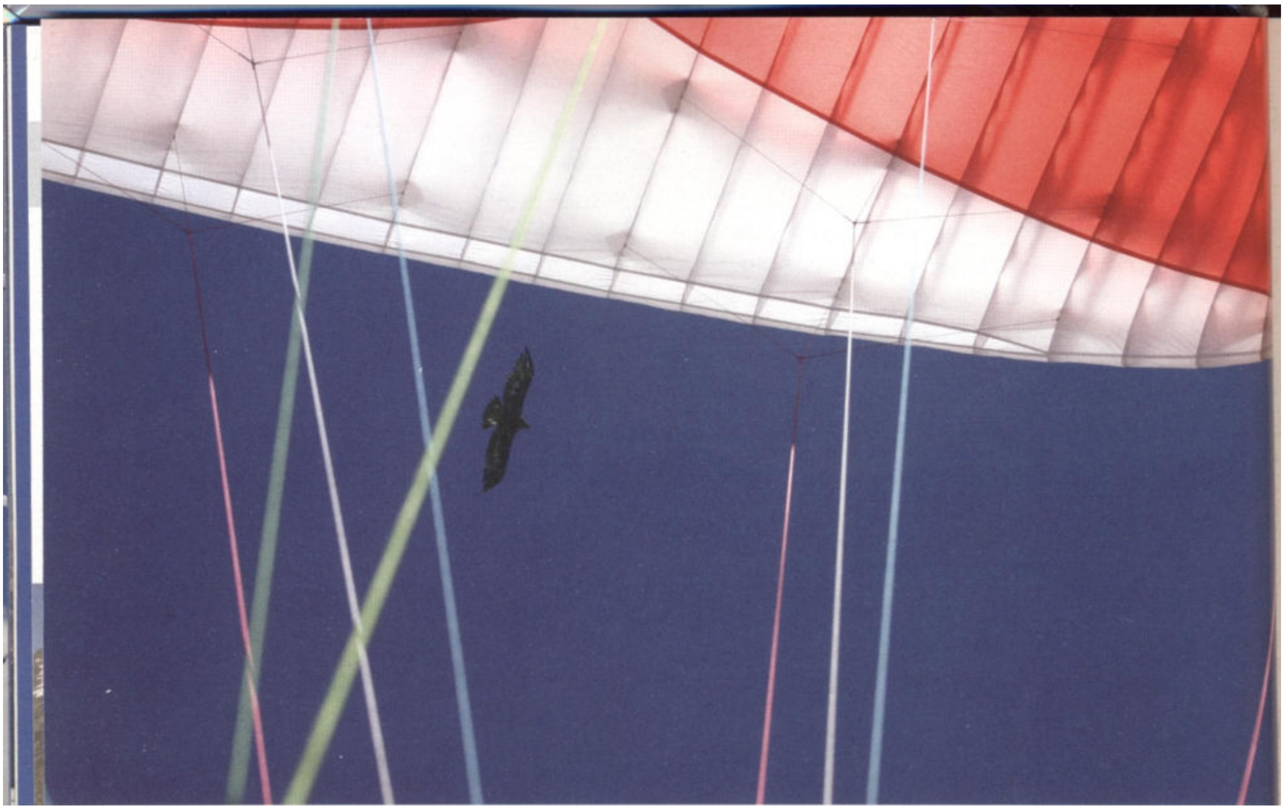
Picture 0.2: Hang glider over the lake Tegernsee, Germany.

The other aspect of this game is the natural impressions gathered through a flight. Sometimes we're thermalling with raptors, sometimes flying over a flock of browsing geese. And almost all the time we're enjoying spectacular views from a perspective that most people can only dream of. When flying over the Dolomites in the Italian Alps I can see the majestic main Alpine divide, an almost uninterrupted snow-covered ridge from horizon to horizon. Does anything really compare to this?

This book does not replace good intuition from experienced professionals. The first thermal experience should be gathered under supervision of a flight school, as strong thermals are not to trifle with.

The book is written from a paraglider pilot perspective, but all but a very few minor details may be directly applied to hang gliding as well. Descriptions of landscape-defined particularities like valley winds or the development of the average thermal strength during the day all refer to the Alpine region, from France to Slovenia, but may be applied to all mountainous regions. Whenever I'm referring to flatland regions this is always clearly stated.

Once you have mastered thermal flying the jump to cross country flying is relatively easy. I wish all fellow pilots all over the world lots of beautiful and exciting flights.



Picture 0.3 A Golden Eagle joined me in a thermal during an August flight in Fiesch, Switzerland.

The interaction with the equipment

To fly well the pilot needs to be in tune with the wing. In other words flying it must be FUN. The passive safety should also correspond to the pilots' experience level, and finally the performance should be adequate. The minimum descent rate for all recent wings is very close, so that if thermalling in normal lift is the only comparison parameter generally the best pilot, and not the best wing, will sit on top of the stack. The performance differences only become visible when gliding, and then only really when gliding at speed. Extreme differences may be seen when gliding at top speed into a headwind, whereas gliding with the wind doesn't tell us much about a wings' performance.

A pilot flying apprehensively under a high-performance wing will get less net performance out of it than he would, if flying assertively with a Sports-Class wing. This is due to the fact that a larger proportion of the pilots' mind capacity is then available for flying tactics and calculations rather than being tied up with worrying about the wing.

Current DHV 1 or 1-2 wings, or EN Standard class respectively, have excellent performance. The first FAI triangle of 120km + was flown on a DHV 1-2 wing way back in 1998! In 2003 Torsten Hahne, a German pilot flying a DHV 2 wing, managed a 180km triangle and secured himself the first place in the German XC League, testimony to the fact that it is the pilot and not the wing doing the big flights. Nobody should be fooled into believing that just switching to a hotter wing will automatically get them further, or even higher. Flying XC is about finding and using lift, about having learned to trust your skills to consciously go to the most likely thermal sources and not just be stumbling around the skies and accidentally happening upon a thermal once in a while. Only when you have reached that level you are truly a XC pilot.

Equipment for thermal flying

Actually you don't really need much. Many pilots fly their first thermals with no vario, no flying boots, no gloves and no flying suit. No problem with that. People even won competitions without a vario. It is just a lot harder, and once we got used to the great little beeper most of us cannot really go any places without it.

So the most important investment, after the glider/harness combo, is the vario. The instrument of choice should have an integrated altimeter, both because flying XC is only allowed with one and because it helps you to develop a "feeling" for altitude - how many vertical metres does a specific transition burn, how high must I be at A to reach B, high enough to connect with the next thermal? Many flights are also undertaken in regions where vertical air space ceilings apply, so to avoid breaking the law, we must know how high we are. The mounting of the vario on either the thigh, the karabiner or on a front container is purely a question of individual preference.

Picture 0.4 A helmet vario is sufficient for thermalling, here the Brauniger IQ Sonic.

Picture 0.5 A high-end vario with integrated GPS is generally a overkill for the beginner. But techies may want one anyway...

Hint:
If your only objective is local thermalling a helmet vario is fully adequate. I have one as reserve on my helmet; if the main one should fail I can always continue with the backup. I also use it for travelling and for tandem flying. The available helmet varios are small and reliable, and come in both battery- and solar powered versions.

Sunglasses protect the eyes, also from the apparent wind, and sunscreen is indispensable at almost any altitude. A balaclava is important for cold days.

Protective clothing like the purpose-built flying suits are also a sensible investment. Paraglider pilots spend far too much time holding their hands in the air at great altitudes, and particularly in the springtime where the air is still cold and the thermals go high, good gloves are important. The best are always a compromise because they must allow the pilot to feel the lines yet be warm enough to fend off the worst cold. The best hint is probably to stick heaters into your gloves. Hang glider pilots have the option to attach big mitts to the base bar where the gloved hand is stuck inside.

Picture 0.6 Normal seating position, not too reclined, not too upright. This allows for perfect weightshifting.

The harness must remain comfortable even during long flights and it should be easy to wriggle in after launch. I like my chest harness to be set around 43cm (17") between the karabiners, and to fly in a semi-reclined position where I feel I have the optimal compromise between parasite drag and the risk of getting twisted in the event of a mishap. Very laid-back flying positions increase the risk of riser twists.

Hint:
The higher the parasite drag of the pilot gets, for example when sitting, or even standing up in the airflow, the higher the descent rates also get. Most people think that the speed decreases proportionally, but in fact the opposite is the case - the speed increases slightly!

The speed bar should not only be attached, it must also be adjusted correctly. When the legs are fully stretched the glider should be going at top speed. For most wings this means that the two pulleys on the risers touch. Short-legged pilots or pilots flying wings with long speedbar travel will often need a speedbar ladder to reach full speed, but these ladders are also useful for just flying at *Vz* speed with the legs stretched out - this is less tiring for the legs.

Picture 0.7 Pulley-to-pulley at top speed. In this picture approximately one more centimetre may be pushed.

Picture 0.8 A little trick to keep the speed bar out of the way when launching. A drawstring stopper holds it up until it is applied the first time in the air. Place the stopper beneath the brummel hook from the speedsystem.

Picture 0.9 Standard speed bar with an angled 1st step to ease the stepping into. The wire loop is used with one foot to get in, then both feet move to the actual rod and slowly accelerate to the desired speed.

The brake length has to be perfect. Brakes that are set too long may pose a safety risk because they don't allow the pilot to control the wing to the max. Brake lines that are to short, diminish the gliding performance and may also be dangerous, as wings that are slowed down unnaturally may not pick up speed again after B-stalls or collapses. The brakes should be adjusted in a position, so

Picture 0.10 My own full XC kit.

that when they will be let loose, absolutely no tension is applied to the trailing edge of the wing. Check the brake line setting in flight by observing the trailing edge and verifying that there's no tension on any of the individual lines.

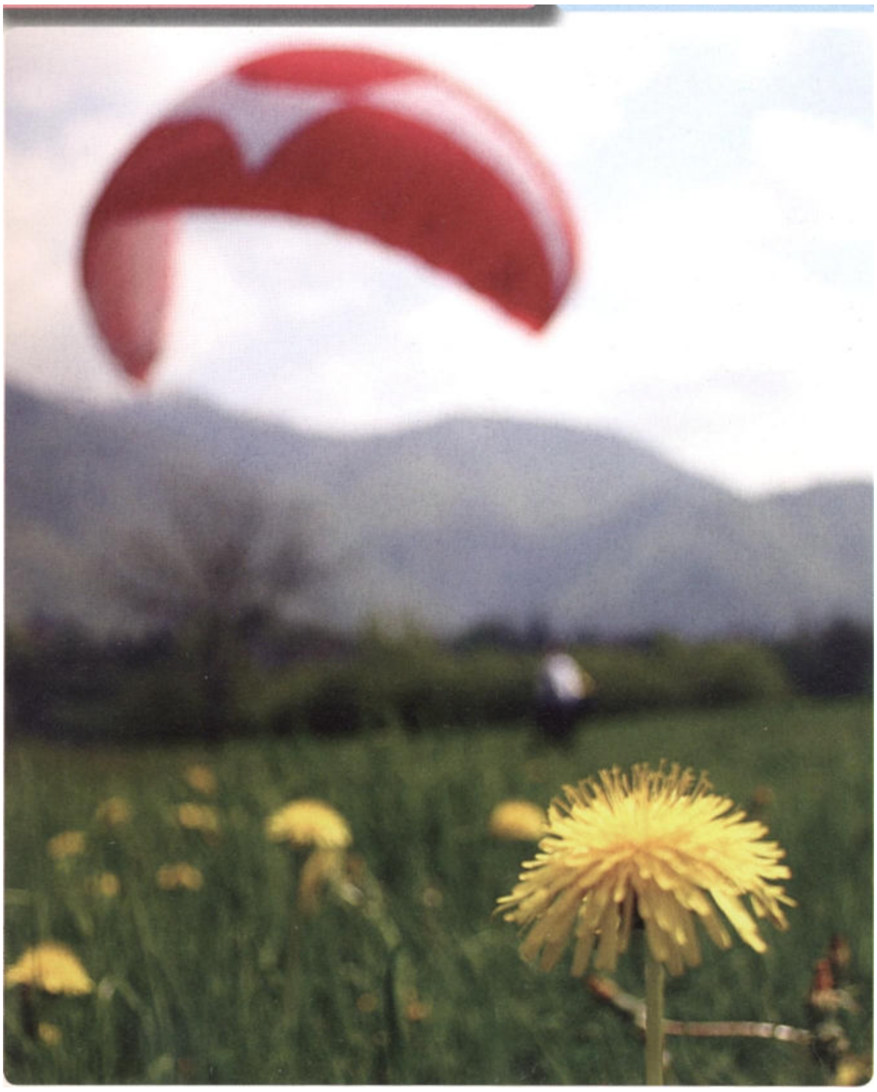
Conversion table

1 inch	=	*2,54 cm*
1 foot	: =	*30,45 cm*
1knot	=	*1,852 km/h*
1 mph	=	*1,61 km/h*
approx. 200 ft/min	=	*1 m/s*

Exiting deep stalls

High sink values combined with little or no apparent wind may indicate that the wing has deep stalled. The quickest way to get it flying again is to either push both A-risers forward or to step on the speed bar.

Hint:
I have my speed bar set up in a position that my legs are always resting on the first step of the ladder. This way all I need to do is stretch my legs to accelerate. Having to fiddle around to find it first is inefficient.



Picture 0.11 Playing with the wind and the wing, landing field, Tolmin, Slovenia.

Chapter 1: Thermals

The first steps; how thermals develop

"Thermals" is the word we use for the general phenomenon of warmer air rising

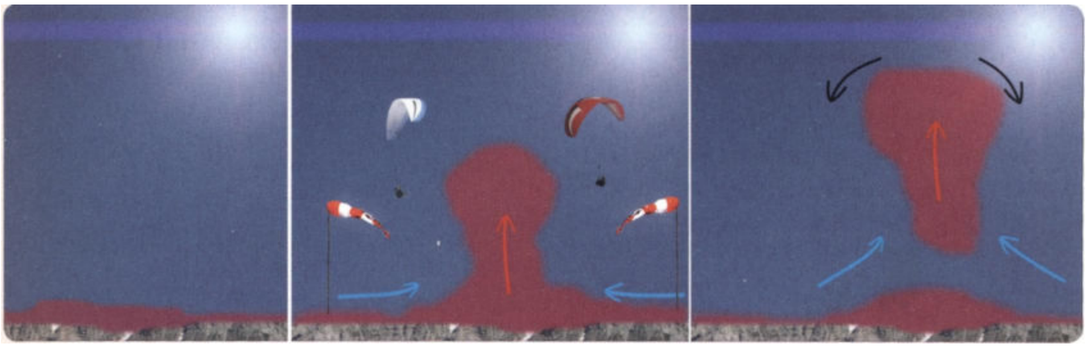
Picture 1.1 Thermalling under a nice cloud in the Soca valley, Slovenia.

through cooler air. The principle is simple: The sun rays heat some section of the ground more than the adjacent ground and this warm soil transfers its heat to the overlying air. Warm air is lighter than cold air, and once the temperature difference is high enough the warm air packet begins to rise. The warmer air does not rise right away due to a certain inertia caused by gravitational forces and simple drag, but once a temperature difference of app. 2 degrees has been reached it will generally release as a thermal. The higher the temperature difference becomes the stronger the thermal will be - this is also the reason why leeside thermals are often stronger, because hidden in the lee an air mass may have time to develop a larger temperature difference than on the windward side where all the air masses are continually stirred and mixed.

The thermal is now born. Its continuation depends on the surrounding air; the higher the temperature gradient (i.e. the steeper the temperature drops with altitude) the faster the thermal rises. The total height gain of the rising air mass also depends on the temperature gradient. When the temperature gradient is high, and the decrease with altitude thus great, we call the atmosphere unstable. When the temperature gradient is low, and the difference between ground level and higher levels is low, we call the

Picture 1.2 Blue thermal, clear air thermal.

atmospheric situation stable. In stable air masses the thermal soon looses its energy and stops, but in unstable air it may rise



Picture 1.3 A thermal is formed: The ground is heated up by the sun and transfers some of the heat to the overlying air. At some stage the temperature difference becomes so great that the binding with the earth no longer holds. The thermal lifts off. Both pilots in the centre photo are flying with a tailwind!

very high. If the air is also humid, and there's no inversion below the dew point, cumulus clouds will develop and mark where the thermals are. When the air is dry, or when the thermals aren't rising very high, the thermals may remain „blue" which means that no cumulus clouds are formed. We normally simply call these „blue" days.

Thermal bubbles, pulsating thermals and thermal columns

When an individual air mass has reached the critical temperature and risen, and the sun is not strong enough to heat the same area sufficiently to keep the thermal fed from below, we call it a thermal bubble. If another bubble forms in the same place shortly it may be considered a pulsating thermal, see the illustration 1.3. It is sometimes possible to actually see the warm air lying on the ground before it releases, just think of the shimmering of hot air over a road on a hot summer day.

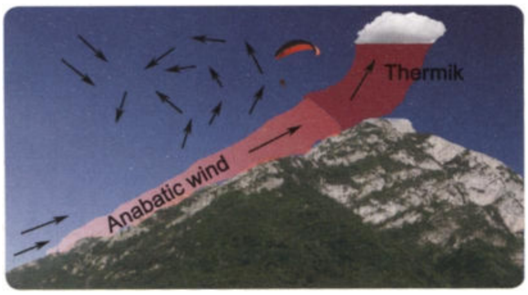
If on the other hand we have a ground section that is receiving a strong influx of the sun's energy, and this is enough to keep feeding the thermal from below, we speak of thermal columns. Because of the topography and the nature of the soil, thermal columns are more common in mountain regions, where a particular rocky mountain flank may be facing directly into the sun for extended periods. The thermals will often flow upwards following the terrain, and only release once they meet a distinct trigger point, sometimes only at the peak. At the

Picture 1.4 A thermal column in the mountains. This cloud will remain where it is for several hours, sometimes smaller, sometimes bigger.

trigger point the thermal column looses its connection with the topography. Such a trigger point is normally fed from several good thermal generators below, which makes it easier to understand why it doesn't run out of warm air to propel upwards. Good trigger points near alpine launches in mountain regions are often called "house thermals" - fly there and you go up. This is then only valid for a specific period of the day, when the sun is reaching the thermal sources feeding the trigger point in question.

Thermal generated wind systems in mountains

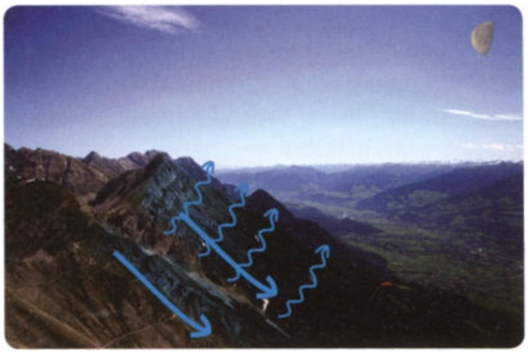
We have learnt that thermals aren't caused by the sun heating the air but rather by the sun heating the ground, which then heats the air. On slopes facing into the sun the air thus heated may begin to flow upwards following the topography at lower temperature differences than what is needed to release a real thermal bubble. We call the winds that result "anabatic winds". You may have noticed that a particular launch site facing into the sun will often also face into wind regardless of the meteorological winds on any given day, thanks to this anabatic wind



Picture 1.5 Anabatic winds caused by the sun heating a slope. Once the flow reaches the crest it releases and becomes a thermal. To replace the air thus disappearing upwards the surrounding air must flow into the area from all around.

flow. This is however also a reason to be particularly alert with regards to windward and leeward sides, as it makes the situation less self-evident than one could sometimes wish.

Once the sun has changed its position in the sky and is no longer heating a particular mountain flank the soil begins to cool down. This immediately cools down the air directly above, and as cold air is heavier than warm the cool air begins to flow down the mountain. This cool downward flow is called "catabatic winds" and these begin to appear as soon as the slope is in shade. On launch sites facing east this may be observed in the



Picture 1.6 Catabatic winds flowing down the mountain. The flow begins almost as soon as the slope is in shade. The wavy arrows symbolise the long-waved radiation of heat to space from earth.

middle of the afternoon, where a back wind will often set in regardless of the macro-meteorological wind direction.

Hint:
Interesting things are present in the spring at many mountain launches. The valley is snow-free but the upper slopes, including the launch, is still covered. Over the snowy sections the cold airflows down catabatically and causes a tailwind on launch in spite of the meteorological wind being straight on!

When there's still snow on the upper reaches of the slopes the thermals coming from below will release at the snow line instead of near the crest. The cold air overlying the snow fields flows down the slope and meets the warm air rising from below, and the thermal is triggered. The thermal even sucks in some of the surrounding air (see illustration 1.3) and thus aggravates the situation, especially if the launch site is situated above the snow line; there'll be tailwind even if the meteorological wind is predicted to be straight on!

Generally it will still be possible to get off though, in one of the following brief phases:

- When the thermal releasing in front and below launch takes a short break
- When a gust of meteorological wind reaches the launch
- Or when just briefly we have no wind

The best launches for such conditions begin rather flat and then become steeper. A no wind launch uses up a lot of runway!

Picture 1.7 The pilot is leaning well forward to put enough energy into his launch procedure in no wind. Don't launch in a tailwind!

Lift versus distance from a ridge

Distance in metres	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**45**	**90**	
Wind speed	**9**	**11**	**13**	**13**	**15**	**15**	**13**	**13**	**9**	**9**
Vertical wind speed (lifting component)	**5,8**	**7,6**	**9,0**	**9,7**	**10**	**9,7**	**9,4**	**9,0**	**6,5**	**5,8**

Researchers in the Inn valley in Austria set out to discover the correlation between the anabatic lift on a sunny ridge and the distance from the ridge. The speeds are all given in km/h.

The research shows that the best lift is not to be found right next to the ridge but 20-30 metres away (marked in yellow above). The reason for this is the drag effect of the topography on the flow. In the instance investigated above, where the flow is 9km/h away from the ridge, it increases to 15km/h near the ridge and the lift is up to 1.5m/s 25 metres from the ridge. The 1.5m/s are the resultant of 10km/h=2.8m/s minus the paraglider sink value, which we set at 1.5m/s in this example.

Conversion table see page 21.

The lift decreases as we distance ourselves more than 25-30 metres from the ridge until, 100 metres away, the ridge's influence on the apparent wind is no longer discernible.

Hint:
Soaring uncomfortably close is normally not beneficial. Besides, keeping a bit more distance will be good for the nerves!

Decent versus distance from a ridge

Once the slopes are in shade the system reverses and the catabatic winds set in. They are not quite as strong as the anabatic winds but the distances are similar or a little shorter. For the pilot this means keeping at least a 100m distance from shadowy slopes, see picture 1.6.

***Picture 1.8** On the right hand slope we can expect lift, on the left one we're pretty sure to encounter increased sinking. The sinking air will be felt as much as 100 metres away from the ridge.*

These rules apply to thermally generated anabatic/catabatic winds and not to macro-meteorological winds. In chapter 8, "Soaring" we delve upon the possibilities that these winds offer the passing pilot. Note that dynamic lift caused by wind meeting an obstacle behave in a slightly different manner; these are frequently useable much further away from the ridge.

Picture 1.9 Soaring at such distances from the terrain is only possible in dynamic lift. Had it been anabatic lift the pilots would be much closer to the slope. Meduno, Italy.

The ideal slope inclination for generating and triggering thermals

A slope facing directly into the sun at right angles warms up better than one that is either steeper or shallower. From this little rule the following can be deducted [1]:

1. In the morning the best lift is to be found coming off steep southeast facing slopes
2. Around noon the best slopes are the ones facing south and with a slightly flatter cross-section
3. In the afternoon we look for southwest facing slopes, and now again the steeper ones are good
4. In the evening we want steep west-facing slopes

Picture 1.11 The renowned Flimser Rock in Switzerland. It faces directly into the evening sun and is steep enough that the sun rays have their full effect. Due to wildlife preservation it is not allowed to approach this ridge low down.

••mmmmmummmmmmmmmmmmmmmm

Picture 1.10 The moderately inclined launch at Fiesch, Switzerland. In the summer this slope delivers reliable thermals from around 11 o'clock AM.

[1] For the Northern Hemisphere. Exchange South with North in the Southern Hemisphere.

Cloud base

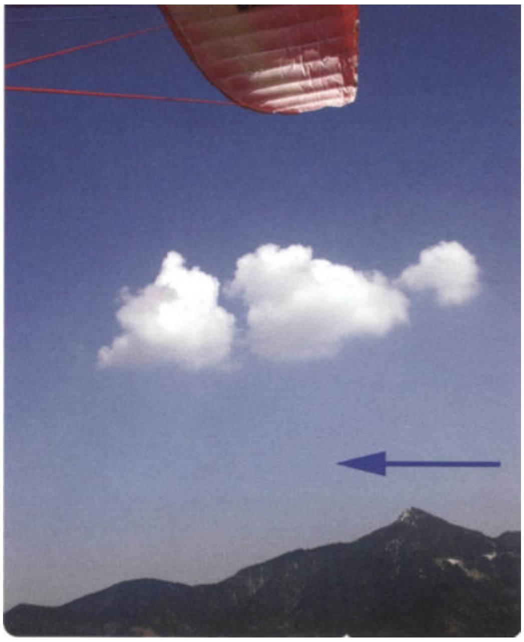
If the thermal has a cumulus cloud forming over it we call the base of the cloud the "cloud base". The very young cumulus cloud needs a little time to properly define the base - in fact morning cumuli often dissolve before the cloud base is even properly defined.

Picture 1.12 Cumulus cloud with well-defined base on the left. We can see that it is the result of 4 thermal pulsations, with the right one being active. Notice the indentation in the base of the right hand cloud section; this is the clue to the active part.

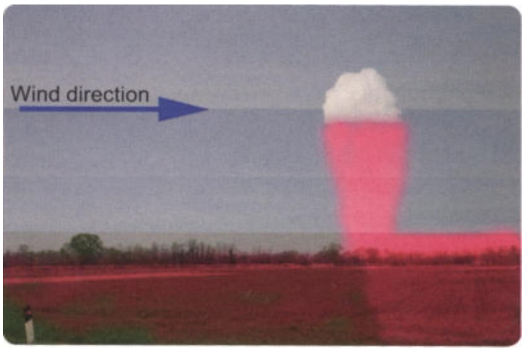
House thermals and wandering thermals

Thermals that originate from a very defined, static source are often referred to as "house thermals". They are very common in the mountains, see picture 1.4.

In the flatlands, particularly on even grounds, we may sometimes encounter "wandering thermals". These originate in one place but are pushed by the wind and continually fed from the warm air encountered by the thermal as it wanders along.



Picture 1.13 Pulsating thermal. The wind comes from the right, which is also where the thermal is generated. The cu's dissolve downwind. If crossing to this cloud we must aim for the little cloud on the right.



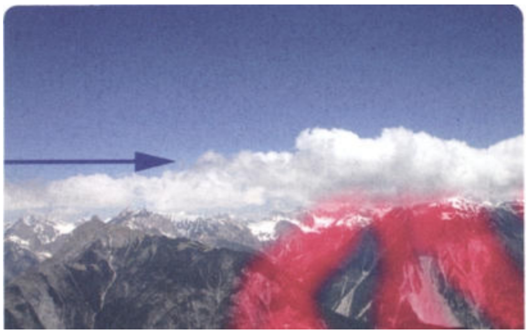
Picture 1.14 Wandering thermal. The wind pushes the entire thermal along so that it continues to receive warm air influx from the ground downwind. After the thermal has passed it takes a while before the ground can feed another thermal.


Picture: Skywalk

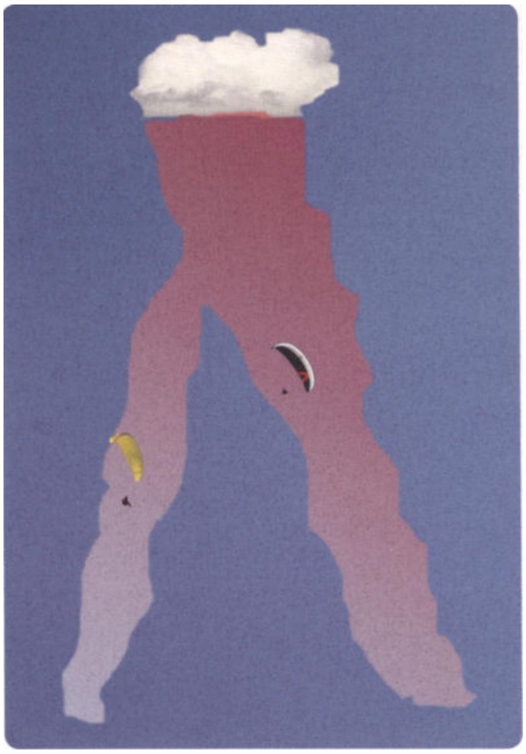
Hint:
When a pulsating thermal is being pushed by the wind we find the next pulsation on the windward side of the previous one. In picture 1.13 the left cloud is dissolving and the right one is just forming - the best climb rates are to be found under the new cloud on the right.

Thermals with several sources

In mountain regions we often find thermals feeding from several heat sources on the ground. This is something to have in mind during thermal-hunting so that we can optimise our glide path accordingly.



Picture 1.15 In this picture it is clear to see how the large cloud is being fed from several sources below.



Picture 1.16 Two thermal cores joining. Above the joining the thermal generally gets stronger and, at least for the left pilot, much wider and easier to centre. In this particular case it is probably not necessary for the left pilot to switch to the right core, see hint below left.

Hint:
The right pilot is climbing better than the left one in picture 1.16. The pilot in the left, weaker core must decide if moving over to the colleague is worthwhile. Generally this is not the case as the loss of time/altitude in the process is high and we can never know how close we are to the joining of the thermals, where the weaker one will also get better.

Experience:
The south face of the Laber near Garmisch in Germany is very thermally active but always in the lee and very turbulent due to the north wind caused by the local Alpine low pressure. The last time I flew to the Laber I aimed for a small crest just south of the main peak instead of battling it out in the lee. My little crest also produced a thermal, which even joined the Laber thermal once I got above the main peak, exactly like it is depicted in picture 1.16.

Thermal duration

How long a thermal remains active depends on several factors. In Europe we get the best conditions following a fresh influx of cold, unstable air masses, i.e. after a cold front has passed through. In these conditions the thermals may begin as early as 10 o'clock AM in the summer. In the evening we expect the thermal activity to shut down one or two hours before sunset.

Once the summer high-pressure has settled in it is common to see a 1-2 hour shortening of the usable time range during the day. This happens less in the spring due to

Picture 1.17 Ground-level inversion in the autumn. The ground fog must evaporate before usable thermals form. The cu's on the right stem from thermals forming on the mountain slopes above the inversion and indicate good flying conditions as long as we stay high.

Picture 1.18 In mountain regions the thermal activity begins earlier in the day than in the flatlands, and lasts longer into the evening. On east-facing rocky slopes they may begin very early whilst steep west-facing rocks may produce gentle lift surprisingly late. Here the Dolomites in Italy.

Picture 1.19 On sunny high-pressure summer days the thermal development in the flatlands is often insufficient, whereas it may still be very good in the mountains. Notice the thick inversion over the flats. Picture shows the Isar valley foothills in Germany.

the more frequent influx of cold, unstable air giving the thermals a boost.

If the opposite situation, where the upper levels receive an influx of warm, stable air should happen the thermals will shut down earlier and generally need a higher excess temperature to rise, see picture 5.6.

In mountain valleys an inversion forms overnight due to the cooling of the ground-

Picture 1.20 The picture shows the Monte Avena launch above Feltre, Italy. Such extreme inversions effectively shut down all usable thermal activity. On this day we could barely remain airborne beneath the inversion but no thermals had the strength to punch through it. The thermal strength was comparable with picture 1.40. We later learned that the day had been really good in the high mountains, with thermal strength comparable with picture 1.38.

level air (in the winter this can often be seen as ground fog). This inversion prevents any thermals from forming at valley bottom level until the sun has dissolved it. Sunny slopes above the inversion may produce usable thermals early in the day; see picture 1.17, but the good climbs only form once the inversion is gone. Older high-pressure situations may see the ground-level inversion last well into the day. There is more about this in chapter 3, Inversions, from page 100.

Thermal strength development during the day

Glider pilots have set up a range of definitions for thermal strength. They apply to the large diameter circles flown by thermalling gliders, much larger than what we are able to do with our nimble aircraft. We can often stay in small, stronger cores and the given definitions are thus somewhat less useful for us.

The following times apply to the high summer in mountains in temperate regions. Assuming a recent influx of fresh cold air masses the thermals may begin to form as early as 8 or 8.30AM, discernible by the little clouds forming over slopes facing east. To remain airborne we do however need something a little more substantial, and this begins to become available around 10 to 11AM. Anyone wishing to fly records should be on their way no later than 11AM, and beginners wishing to learn thermalling are also advised to launch now. From noon the thermal development is at the most reliable and the strongest time, between 1 and 3PM, is when the XC pilot can really make some distance - this is then also the time when the conditions are most demanding. From 4PM we begin to notice a weakening, making the air suitable for beginners once again, and from 6PM the thermals become weak enough that only exerienced pilots will usually remain flying. Those will then sometimes be able to keep going until 8PM.

The following values are meant as a suggestion only.

Weak conditions for climb rates up to 1m/s
Medium - for climb rates between 1 and 3m/s (200 - 600ft/min)
Strong - between 3 and 5m/s
Very strong - between 5 and 8m/s
Extreme conditions above 8m/s; values of up to 15m/s have been recorded!

Note: 1 m/s is approx. 200 ft/min

***Picture 1.21** The first gentle wisps are beginning to appear, and the Swiss XC experts still have 30-60 minutes to get prepared. Now is the ideal time for beginners to learn about thermal flight.*

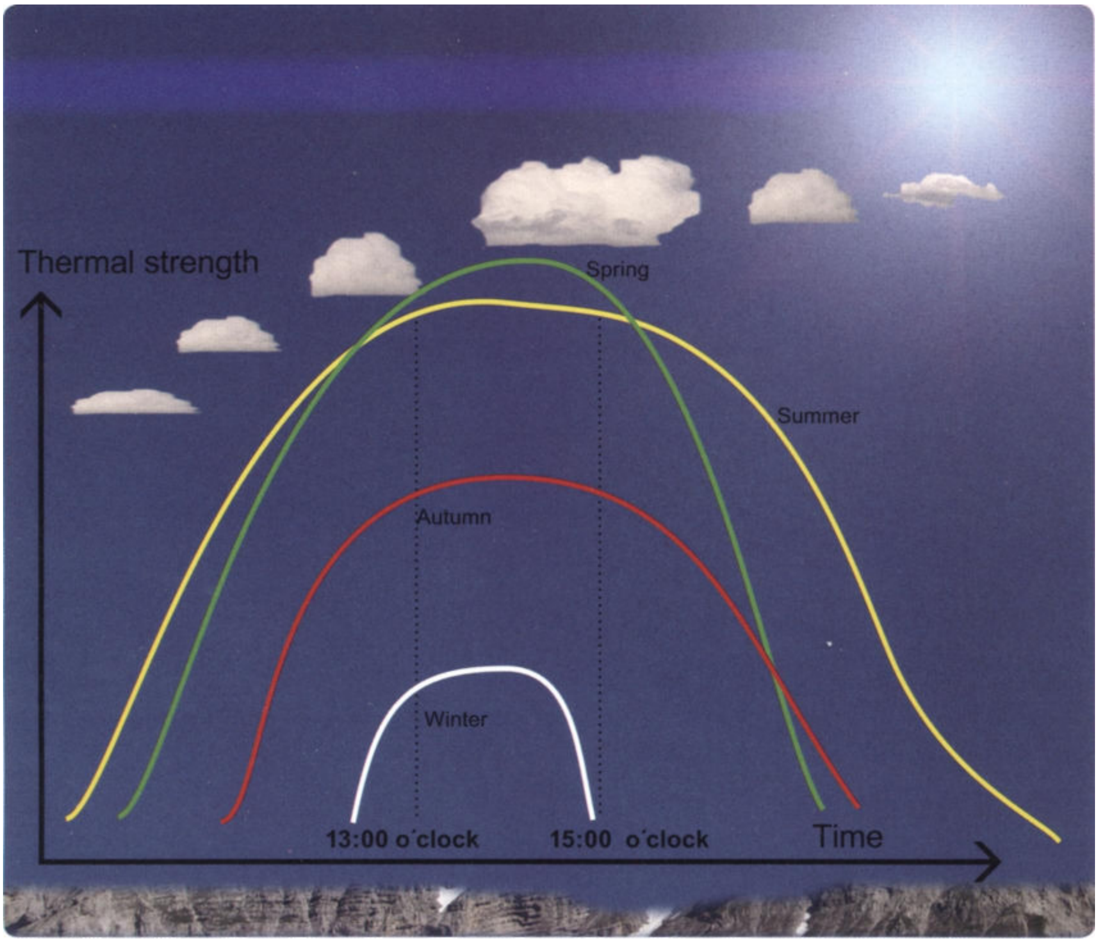


Illustration 1.22 Diagram of the thermal strength as a function of time in temperate regions, with all seasons given. The cu's above apply to the yellow summer curve.

These values apply to the peak vario readings, often only seen for brief moments during thermalling. A thermal averaging 3m/s over several minutes will surely have shown several peaks of 6-8m/s on the vario.

Large thermals are generally calmer and easier to core than small ones, where even experienced pilots often find themselves falling out the side now and again.

Conversion table see page 21.

Experience:
My own strongest climb ever was up to 12 *ls,* and in total I have had less than 10 thermals showing more than 10m/s on my vario in 19 years and more than 3300 flights.

Hint:
Strong thermals are generally also more turbulent. This is the reason why it is not recommended that beginners fly during the strongest time of the day. The best time to gather the first thermal experience is in the mornings and late afternoons.

Thermal strength over the seasons

In springtime in temperate zones the air is generally unstable and the thermal activity begins earlier in the day, almost as early as in summer. Due to the lower angle of the sun it does however shut down one or two hours earlier - April in the Alps sees the last thermal activity around 6PM. In the autumn the thermals begin 1-2 hours later than in summer, and end as early as one

Picture 1.23 Winter thermalling: Sadly a rare occurrence, and a weak one too. Generally encountered over snow-free south facing slopes. In extremely cold and unstable air winter thermals may however form even over snow-clad forest slopes.

or two hours before sunset. If any thermals form during the Alpine winter it will normally only be at the height of the day, i.e. around 12.30 to 2PM.

Winter thermals are almost always very weak, whereas the spring thermals are renowned for their intensity. This is due to the generally cold air mass present, where even modest amounts of sun can cause a huge temperature difference, see picture 1.26. This in turn makes the springtime into the most virulent and demanding season to fly, not to mention the extreme cold generally experienced at an altitude this time of year.

On April 20th the days are about as long as on August 20th. An analysis of the XC flights undertaken throughout the year shows that the longest flights in Europe are

Picture 1.24 Spring thermalling: Much more common and always a cold experience. The cloud base is high, and the thermals are strong and rough. The picture shows the Ahrntal in Alto Adige, Italy.

also flown during this time span. From April till June the thermals are strong and turbulent, from June this turbulence decreases and in August the thermals are generally relatively weak again. This does not however fully apply to central mountain regions like the inner Alps, where the strength and turbulence only decreases in September, or in places like the Dolomites where it may continue into October. In late autumn the thermal activity is low everywhere.

Increasing stability as the year passes

By Volker Schwaniz

Experienced pilots know it well; the best thermals are to be found during springtime. And this in spite of the fact that the summer has far higher temperatures and also more sunlight. So how can it be? The key to understanding this is insight into the development of the temperature at altitude during the year - because a difference in temperature between ground level and higher levels is a prerequisite for thermal development.

The orange graph shows the number of possible sunlight hours (indicating the possible ground heating effect) during the course of the year. In the northern hemisphere the

Picture 1.25 Autumn thermalling: Often gentler, weaker, strongest in central mountain regions. In the flatlands generally too weak to use. The picture shows a pilot climbing above peak altitude in front of the Drei Zinnen (Three Peaks) in the Italian Dolomites. The fog-clad valley in the background is the Hochpustertal in Austria.

maximum is reached on June 21st, and the minimum on December 21st. The black graph, and the blue area beneath it, show the average temperature at 1500m NN in the Alpine region. The horizontal parallel offset of the two graphs makes it beautifully clear that the yearly heating of the entire air mass is lagging behind the maximum available sunlight, and the excess energy thus available is greatest in the spring (the yellow area). This equals stronger thermals!

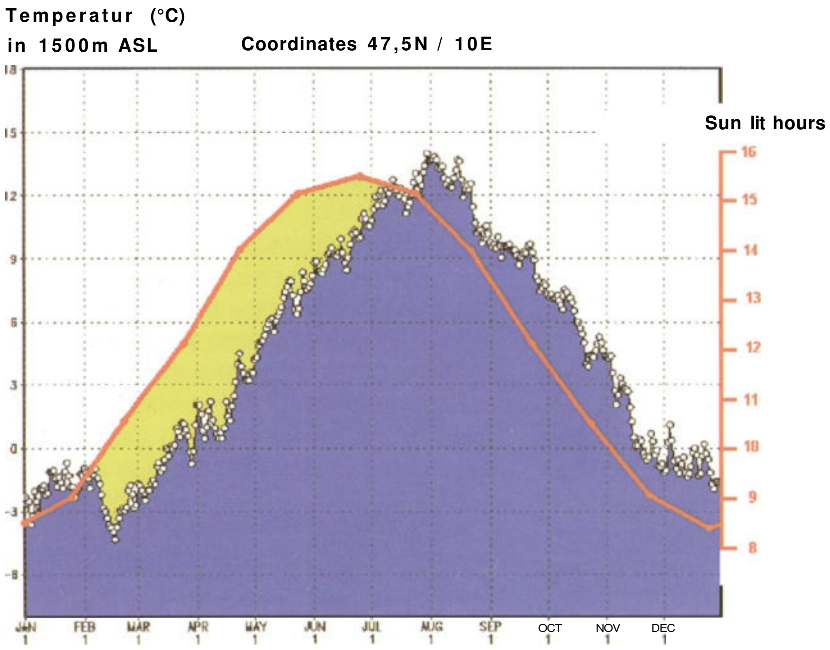


Illustration 1.26 Temperature development at 1500m ASL and sunlight hours as function of time around Arlberg/Austria. The temperature (blue area) lags behind the sunlight in the spring (yellow area) but is ahead in the autumn, which causes the increasing stability that we observe during the course of the year. Illustration by Volker Schwaniz.

At the height of summer the intensity of the sunlight begins to weaken but the temperature at altitude still rises for quite some time, and this is exactly the cause for the increasing stability; for when the intensity of the sunlight decreases but the increase of temperature at altitude continues we have two factors, both contributing to the weakening of the thermal activity, both active at once. And although our senses tell us that we're right in the middle of the warm season, the place where the graphs meet is already behind us and the premises for the development of high and strong thermals have already deteriorated significantly within a very short time span.

If a high-pressure situation sets in we get an additional stable air mass with little temperature difference from ground level and up, which only ads to the negative equation. And finally the warm summer air can contain much more humidity, which increases the risk of thunderstorms developing

Picture 1.27 Oily Rossel in Greifenburg, Austria.

Why is cold air more unstable than warm air?

The stability of a given air mass does not depend primarily on the temperature, but on the temperature gradient. The temperature gradient indicates the decrease in temperature as function of altitude, see also chapter 9. However, the temperature itself also plays a role:

Warm air can contain more humidity than cold air. When heating the air, the water vapour contained herein must also be heated, and this process requires more energy. The energy thus spent is not available for heating the air, which means that humid air heats slower than dry air. This is one of the reasons why the spring thermals are better and stronger - the air that forms them contains less humidity and can be heated quicker.

But according to Volker Schwaniz the main reason why warm air impedes thermal development is the fact that the temperature gradient is less pronounced. A layer of warm, humid air lies on top of the ground layer and effectively stops the thermals before they get going.

Visualising thermals

To bad that air is invisible, no matter if could or warm. So to get the most of the conditions we need to be able to build a mental picture of the thermal we're circling in, to visualise it in our minds, see picture 1.4.

Some thermals are very large and may even be kilometres long, for example under long cloud streets. Others are small, narrow, or made up of several cores each showing significantly different climb rates. In the next pages we'll be showing a number of different thermal structures, to help you in your own visualisation process.

Picture 1.28 Four cumulus clouds forming. The ring shape indicates the presence of a vortex structure.

The vortex structure of thermals

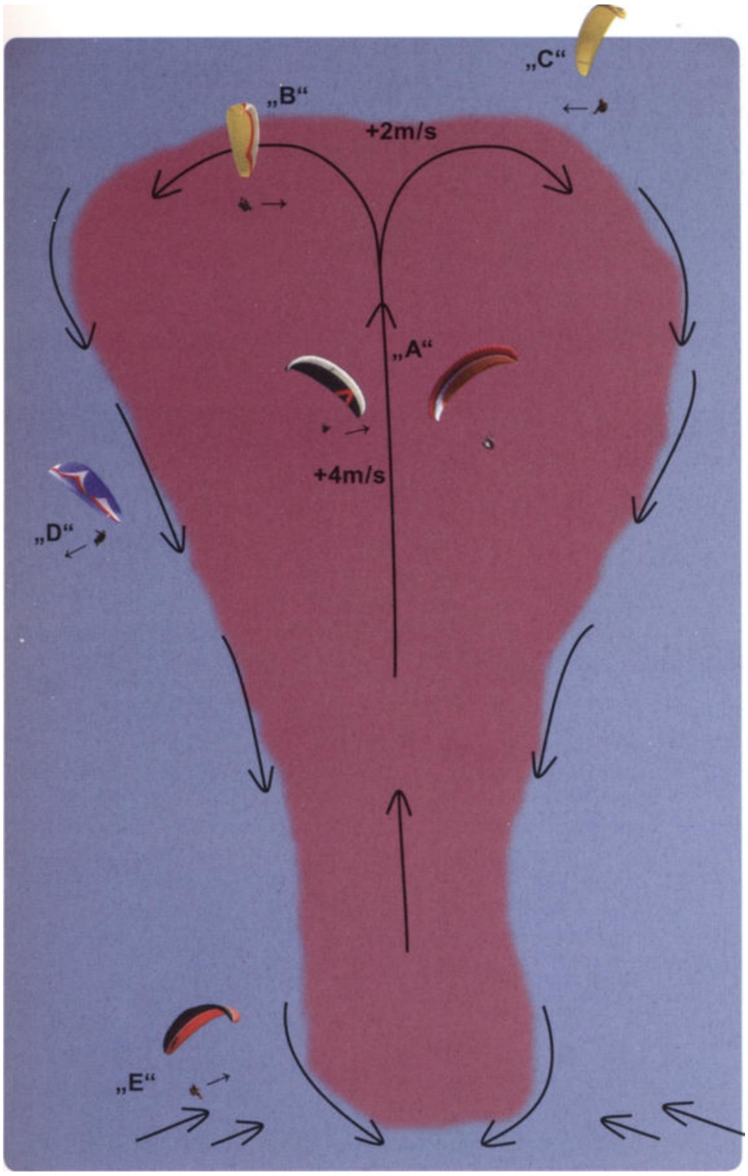
Smoke rings blown by cigarette aficionados give a good visual clue as to the structure of thermal vortices.

We know from experience that the thermal is several times stronger in its core than closer to the edges. Why is that so? To explain it, the vortex-structure theory was developed. The accuracy of the theory can be affirmed often enough through observations: When the thermal rises the friction against the surrounding air slows it down along the edges. This sets off a rotating movement from the inside out, like when we turn out a sock. These vortices may be observed both in thermal bubbles and in thermal columns.

Conversion table see page 21.

Note: 1 m/s is approx. 200 ft/min

Experience:
I had the most amazing experience surfing a vortex ring in a very strong thermal once. I was going up at 9+m/s on a no-wind day, and suddenly realised by looking at my GPS that my forward speed had gone to zero! At the time I was thinking hard about where that very strong headwind had suddenly come from, but today I realise that I was simply at the apex of the vortex ring, pointing right into the outflowing air (see illustration 1.29, pilot B). I eventually made 1500m vertically in very little time, flying straight and remaining practically on the spot! Impressive!



Ill. 1.29 The vortex structure of thermals; an example of how an idealised thermal could look if only we could see it. The net climb rate of the entire thermal may be 2m/s but in the core, by „A", we may experience 4m/s whereas the edges get only 1m/s. The horizontal component by „B" can be surprisingly strong - up to 30km/h in my experience.

Lets look at the significance of this vortex-ring structure for the pilots A to E:

Pilot A is in the core and climbing twice as fast as pilot B, who is at the apex of the climb. Once pilot A catches up with B they will continue with identical climb rates.

Pilot B is flying against the head wind caused by the vortex ring. If he's carrying a GPS he may notice that his ground speed is lower than it was shortly before. If he flies over the centre of the core he'll suddenly have a tailwind combined with lower climb rates. It is possible to sense the acceleration when moving over the core and into the tailwind, and the pilot should turn immediately to stay in the core and maximise his climb. The core of the vortex ring is rather turbulent and the pilot must continuously respond to the pitching of his wing and carry out adjustments to remain in the strongest lift. /

Pilot C is still above the thermal. Only when he descended down to the level, and it has climbed up to meet him, may he commence thermalling and gaining altitude.

Pilot D has fallen out of the side of the thermal and is heading away. Provided he's carrying a GPS he may notice his ground speed picking up whilst his descent rate is also increasing.

Pilot E is approaching the thermal low down. He has a tailwind and already should see reduced descent - he's practically being sucked into the thermal.

The example above shows how important it is for each of us to always try to build up a mental picture of the thermal we're in; to visualise it. Only by doing so may we understand what is going on all the time in relation to which part of the thermal we're in, and make the most out of it. This also allows us to re-enter the core quicker in case we loose it.

Hint:
If I'm flying straight and suddenly feel an increased drift towards one side, maybe even combined with reduced sinking, I always follow the drift immediately. Chances are I'll fly right into a thermal, just like pilot E is about to do.

Picture 1.30 An example of a cloud under which we may often encounter vortex rings. Chances are they'll be isolated and small.

Picture 1.31 A cloud showing classic vortex shape. By looking at such clouds we may learn a lot about the structure of the invisible thermals.

The tail end of an isolated vortex ring rising

Lets imagine two pilots trying to exploit the lower end of a thermal bubble rising as a vortex structure; one is 50m lower and soon gets left behind by the bubble, which due to his sinking through the surrounding air mass is always rising faster than him. But the other pilot who is 50m higher makes it into the centre of the vortex ring, where the rising air is accelerated by the vortex structure. In spite of the thermal bubble rising with 1m/s (200ft/min) the centre is producing climb rates of 2m/s which just balances out the descent of the paraglider. If it wasn't for this effect, and assuming a min descent of -1m/s, the upper pilot would descend out of the bottom of the thermal bubble in 50 seconds (he was 50m higher than his buddy) - but instead he goes with it all the way to cloud base!

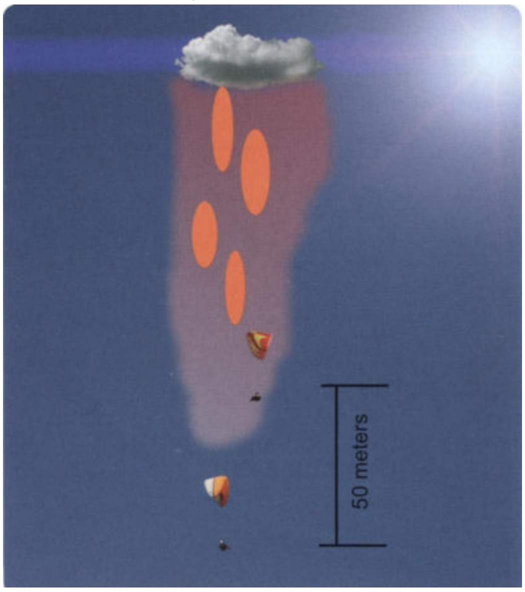


Illustration 1.32 A thermal bubble rising. The lower pilot looses it early on, and searches in vain for the now much higher thermal. The upper pilot just makes it into the centre of the vortex ring, where he manages to remain. The lower pilot can only watch as his buddy becomes smaller and smaller.

Within the thermal are several "hotspots" where the lift may be even better.

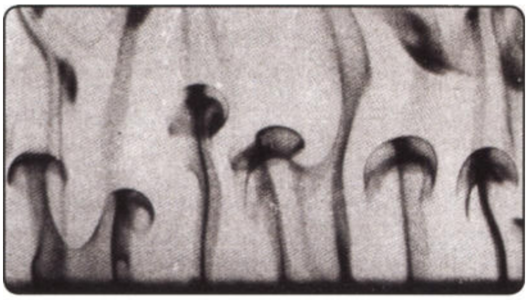
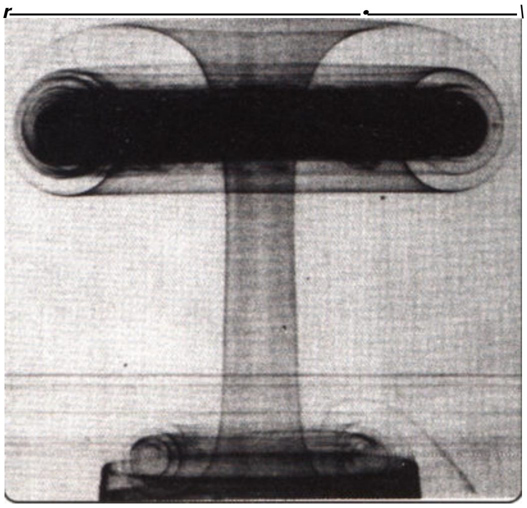


Illustration 1.33 These pictures were produced by the University of Stanford in California. They show oil being heated by a hot plate, with "thermals" rising from the bottom. The photo above shows the ideal situation, with beautifully formed and regular shapes. The lower picture shows the same situation but now the hot plate has been turned up too high; the "thermals" rise too fast and in a chaotic manner. This compares well to lee thermals or to airmasses where the temperature gradient is too high, see also page 219: A temperature gradient of minus 0.9 - 1.0 deg/100m.

Illustration 1.34 In this enlargement the vortex structure is particularly visible.



Hint:
Vortex rings are commonplace among isolated thermals with narrow cores. When the thermals grow large, as they do under cloud streets etc. the structure is rare.

Sinking air surrounding the thermals

The good pilot is always trying to work out where in the thermal he will be. The air itself offers some valuable clues here.

Up high, and right on the outside of the thermal, we find not only increased descent but also a drift away from the thermal. To find it we need to turn against the drift. Down low the situation is inversed; the thermal sucks in surrounding air, which results in a light drift towards the lift combined with slightly reduced descent.

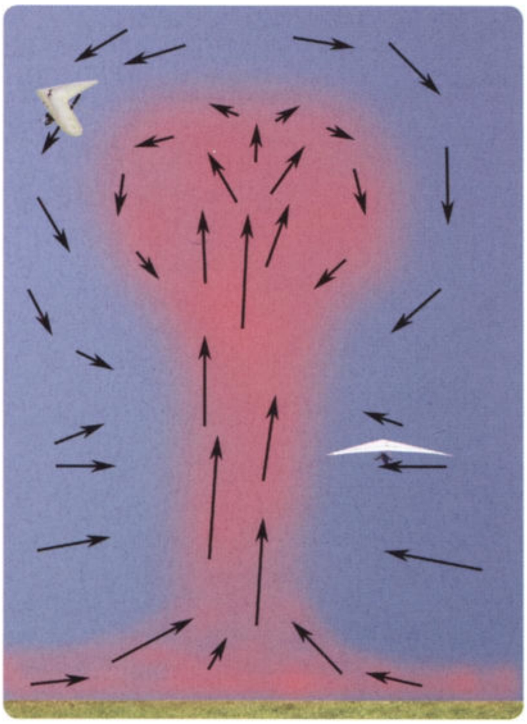


Illustration 1.35 Air movements around a thermal: The higher hang glider is experiencing increased descent rates and a light tailwind component, whereas the lower one is being sucked in by the thermal.

Researching thermals

Scientific approaches to the measurement of thermals have often shown far more complex patterns than what we see in illustration 1.35. If we look at Illustration 1.37 we can see an example of a thermal splitting up into two cores, where one reaches all the way to the cloud base whereas the other suddenly stops. The reason is likely linked to the sinking air surrounding the thermal, where a part of it has managed to wedge into the lifting air and putting a lid on some of it.

The paraglider in the illustration is not too far from the still climbing hang glider. The former may think that he's continually dropping out of the side of the thermal but in reality his core has stopped climbing. His best approach is to move over to the hang glider, now above him, and continue climbing there.

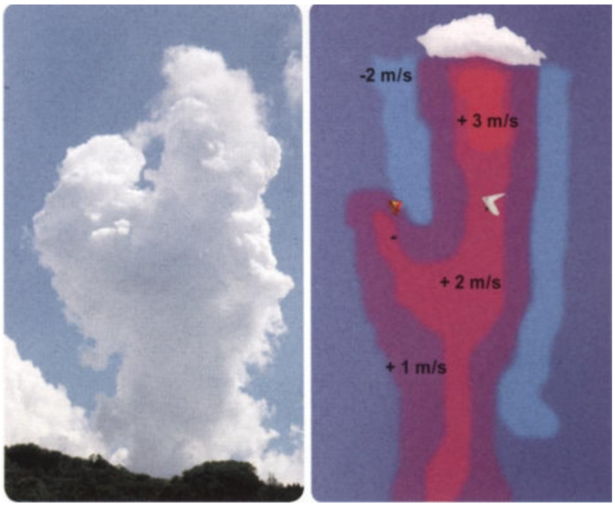


Illustration 1.37 Sketch of a real thermal as it was determined during a test flight, with wings added for illustrative purposes. The hang glider has centred the better core whilst the paraglider is in a dead end. The picture on the right matches the illustration well - good for visualising what happens.

Hint:
Whenever I see proper cumulus clouds above me I know that there's a way to get up there. So when I find myself in a dead end like the paraglider in illustration 1.37 I simply increase my turning radius until I reencounter the good core.
I like flying alone a lot, but there's no arguing that exploiting difficult thermals like the ones shown here is much easier when flying in a gaggle.

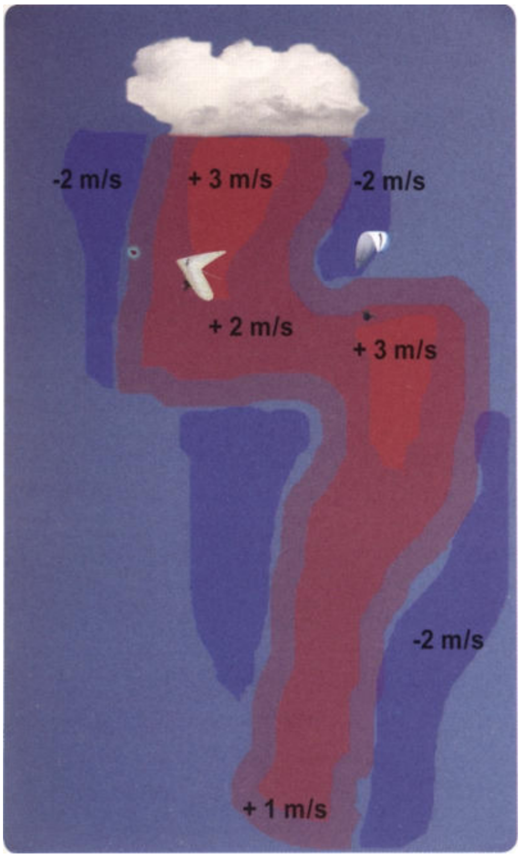


Illustration 1.36 A thermal moving through a wind shear. Anyone remaining in the right hand side will not be able to climb to the cloud base, as the thermal has been pushed to the side. By moving over to the hang glider the paraglider may still continue to climb. If we're alone, without other pilots around to show the lifting air, it pays to increase the centring radius in the direction of the drift.

The influence of airmass (in)stability on thermal strength

We have seen that the available instability of a given airmass influences how high the thermals may go. But it also dictates the strength of the thermals, and where the best climbing may be found.

Thermal strength (red line) as a function of altitude. The further away from the Y-axis of the coordinate system (left picture border) the stronger the thermal.

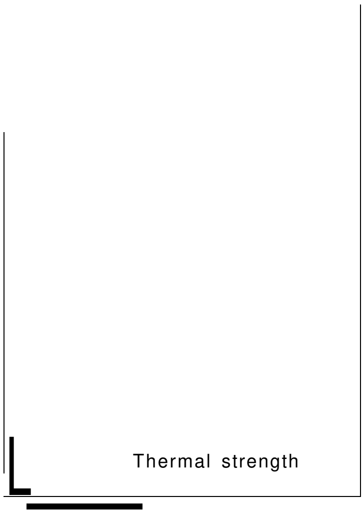


Illustration 1.38 The airmass is basically unstable, but there's a high inversion laying a lid on things (see the red graph, indicating the temperature decrease with altitude). From experience we know that the thermal reaches its peak climb values in the upper third. Shortly before reaching cloud base the thermal looses its momentum, and getting all the way to cloud base is a patience-game. That's why the risk of getting sucked in this scenario in minimal. This is the most common situation in the Alps.

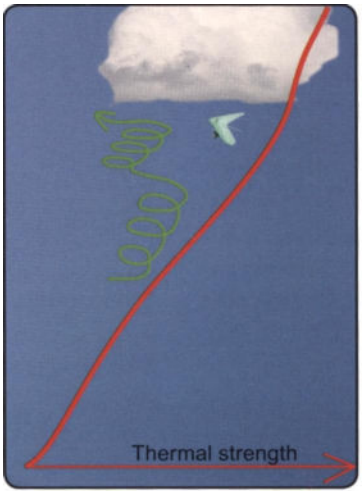


Illustration 1.39 The situation shown here is the 2nd most common one in the Alps; the instability continues way above the cloud base, which means that there's no inversion stopping the thermals from rising high. The climb rates continue to improve all the way to the cloud base and the clouds grow very big. It is easy to get sucked into the clouds and pilots should attempt to move to the edge of the climb well before reaching the cloud base (see the green line). Once at cloud base it is easy to move away just as the first wisps of a cloud begin to ap-

Illustration 1.40 A stable airmass. The air is indifferently warm both high and low. If the sun is strong thermals may still form, but the stable air soon stops them. Birds still manage to get decent flights but they never get up very high.

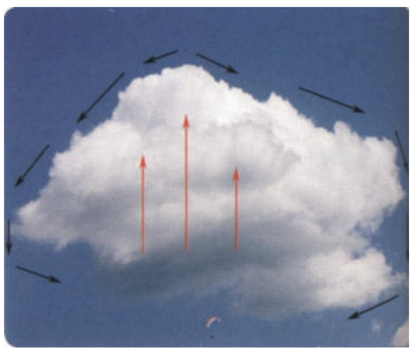


Illustration 1.41 Dampening of the thermal under a small cumulus cloud. The cloud is surrounded by cold sinking air. As it sinks this air warms up around +1°C/100m, or somewhat more than the rising air inside the cloud cools down (-0.65°C/100m), see also chapter 9. The warmer air sinking down around the thermal slows it down to the extent that the cloud base may remain out of reach for the pilot beneath! After V. Schwaniz.

the best XC-days 2006. Drauvalley by Lienz, Austria.

Thermal development in stable air

The sun is strong, but the thermals still won't really form - a typical scenario in the late summer or early autumn, when a high-pressure system has been stationary for a few days (Illustration 1.40). Gliding close to the valley floor we suddenly encounter a small, turbulent thermal that is very hard to centre and only delays the inevitable for a few moments - and the climb rates deteriorate rapidly with the few metres of height gain we manage to make; a classic stat of affairs on a stable day. Such days are really not very satisfying; the overheated air punches little thermals up that quickly loose momentum, only managing to stir up the air in an unpleasant way, enough to make it turbulent but never enough to get up high. Picture 1.20 shows such a day.

Hint:
Flying according to the day quality
On days when the thermals increase in strength all the way to the cloud base I always try to remain as high as possible.
On the more common days where the thermal weakens a little right below cloud base I only bother to go all the way up if I have a wide valley crossing ahead of me - otherwise I leave the thermals as they grow weaker and push on.
There are also days where the thermals are good down low, then around a certain altitude they get bumpy and weak, and above this layer they increase again. These days are easily recognised from the temperature gradient printouts (Chapter 9). On such days I try hard to remain above the inversion causing the slowdown as every visit below costs too much in time and tension batteling my way back up.

It is like magic: Cold advection ...

If the stationary high pressure is coming under the influence of a cold advection, where cooler air is pushing in at higher levels to replace the warm air present, the entire airmass becomes less stable and the thermal quality improves. If the influx of cold air persists into the evening we can have fantastic evening flights where the high peaks keep producing good thermals until sunset.

How to recognise cold advection?

In the Northern hemisphere the high level wind is normally turning 20-30" more to the right, in mountains even 30-40°, compared to the ground level winds. This is due to ground friction. But when there's a cold advection happening the situation reverses - the high level winds are turning to the left instead (it works vice versa in the Southern hemisphere). By watching the high clouds we can learn to identify such a situation. In the Alps it is common with easterly winds, where the air influx is from the North and generally cooler.

Picture 1.42 Cold advection: When the high-altitude winds suddenly turn counter-clockwise (as opposed to the normal' clockwise turning) we know that there is cold air flowing into the area up high. This means unstable air and good thermal development. We recognise it by comparing the drift of the high cirrus clouds with the ground wind. In this picture the pilot in launching from Mount Lema in Switzerland, cirrus clouds in the background.

'1n the Northern Hemisphere - it works the other way around south of the Equator.

Hint:
Cross Country beginners should always try to remain as high as possible (remember to check if there are airspace regulations in your area). Doing so prolongs the flight and leaves more time for learning.
Heinz Huth is a double World Champion glider pilot. He has named it thermal hunting according to the Huth Model, or the "Forest Theory".

He compares the novice thermal chaser to a person running through the forest blindfolded. Every once in a while the person runs into a tree - sometimes a big one, sometimes a smaller one. Fortunately the thermal development in the mountains is a great deal more predictable than that, and accomplished flatland pilots even learn to read the terrain and the clouds to the extent that at least part of their blindfold comes down.

Picture 1.44 High-Alpine flying near Fiesch, Switzerland. Plenty of big and strong thermals, but also smaller/weaker ones in between. If the pilot is in a hurry and has the skills he only uses the strong ones, but a novice or someone just out to enjoy the views should take every climb he finds.

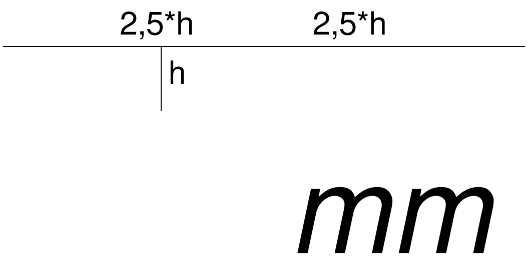
Hint:
Experience has taught me that thermals will often show a great deal of similarity on any given day; if the last thermal was improving all the way to cloud base chances are that the next one will be exactly the same.

Picture 1.43 Flatland flying. The photo shows a planned route for a flight near Munich in Germany. The pilot takes every thermal as high as he can - in the flats staying high is even more important than in the mountains, where a ridge facing into the valley wind can often save the low pilot from a premature landing. This is almost never possible in flatland flying, which means that a lost thermal MUST be found again because we cannot just fly to the next expected lift zone - unless of course we can see other pilots, or birds, thermalling better within gliding distance.

Thermal spacing in the flatlands

Practical surveys have shown that an average thermal has a diameter of approximately 1000m up high - easy enough to stay in! But the core, where the climbing is good, is much smaller, maybe 50-100m across or even less. The distance between thermals in uniform flatland is generally 2.5xheight, which translates into the following little rule of thumb: The higher the cloud base, the further to the next thermal! Smaller thermals between the proper ones may be found, but they often don't make it all the way to cloud base.

All these values apply to the homogenous ground on no-wind days. As soon as there is wind the picture becomes less schematic, and from only 15km/h wind lift bands, cloudstreets may begin to form.



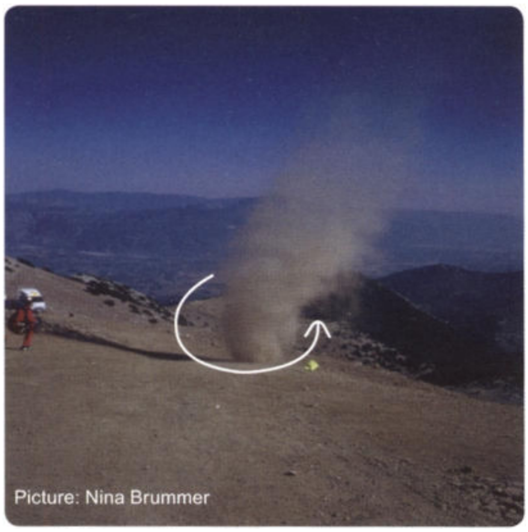
Picture 1.45 The distance between flatland thermals is generally assumed to be 2.5x their height above ground.

Rotating thermals

Contrary to popular belief the thermal rotating direction is not defined by the coreolis force. Thermals will often rotate, but in random direction.

Experience:
I experienced a perfect example of a rotating thermal in Bassano, Italy once: I was thermalling in a beautiful 3m/s thermal, turning left. A little leaf popped up next to me, also spiralling left. I increased my radius and kept the leaf in sight on my left wingtip, and "we" continued to thermal together. But the leaf was climbing about a metre/circle faster than me and soon left me behind. The experience showed clearly how thermals are sometimes not only rotating inside out (page 40) but also around themselves vertically.
A second incident happened in Valle de Abdalajis in Spain. A number of plastic bags had been blown together by the wind on a little garbage dump, and the thermal triggered right off the crest of the dump, sucking in all the plastic bags. It was beautiful to watch the many colourful bags dancing left as they ascended.

Hint:
Dustdevils show the thermal rotation very clearly.



Picture 1.46 Dustdevils are rotating thermals being born. The picture shows the Babadag launch in Oludeniz/Turkey. Empirical studies confirm that they turn randomly left or right everywhere on the Planet.

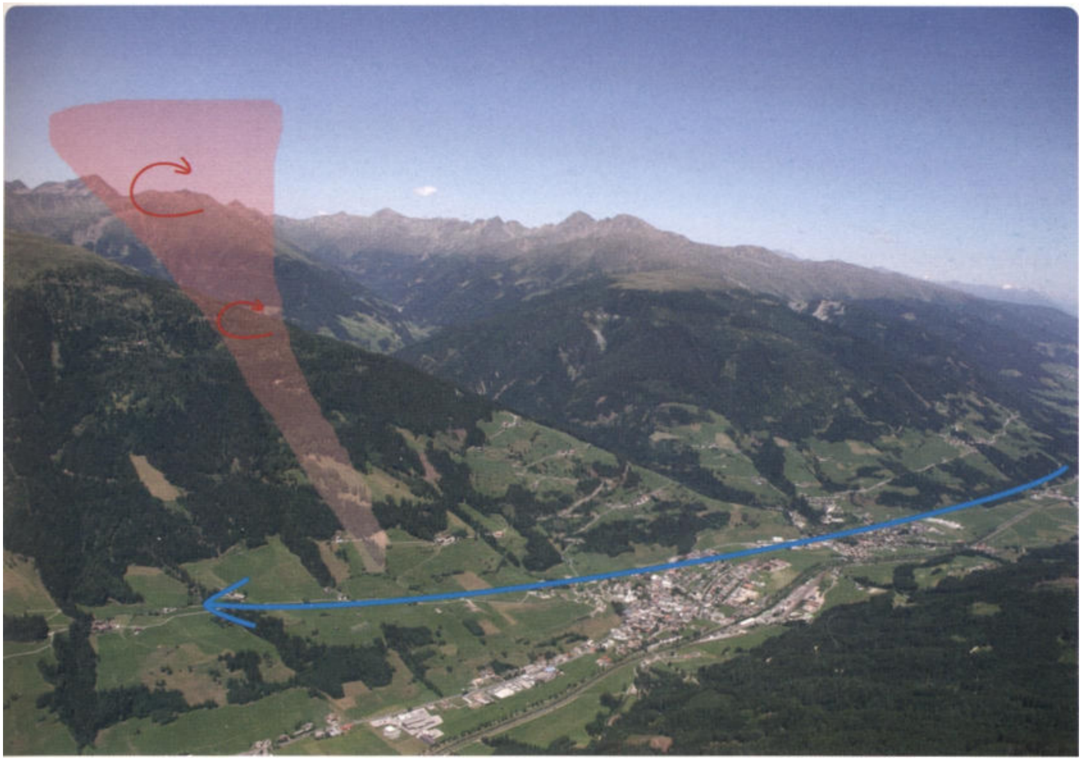
Hint:

Some experienced pilots have speculated that thermalling against the thermal rotation will improve climb rates. If this is true then we need to be able to discern the rotation of a thermal before joining it. The flying meteorologist Sven Ploger has presented a usable hypothesis for mountain conditions: The rotation is determined by the release impulse. An example could be a warm air bubble lying at the bottom of a N-S oriented valley, with the valley wind blowing from the north. According to this theory thermals triggered near the west side of the valley or on the western slopes will rotate clockwise, respectively counter-clockwise on the east side. I have yet to verify this hypothesis but will be observing it carefully to see if it holds.

Experience:

Peter Karsten is a friend who has an office window facing a popular "house thermal" often filled with buzzards. Ever since reading the first edition of my book he set out to ascertain whether acknowledged experts like the buzzards had a preferred turn direction. In one year of studies he was unable to observe any tendency either way - indeed the buzzards would often reverse theirturn direction! But i remain unconvinced that there is no benefit to turning against the flow in thermals, and will keep researching the subject!

Picture 1.47 Sven Plogers thermal rotation hypothesis: The triggering impulse determines the rotation direction so that when, in this example, the wind sets off a thermal on the far side of the valley this thermal rotates clockwise whereas on this side it will rotate counter-clockwise. Sillian, Austria.

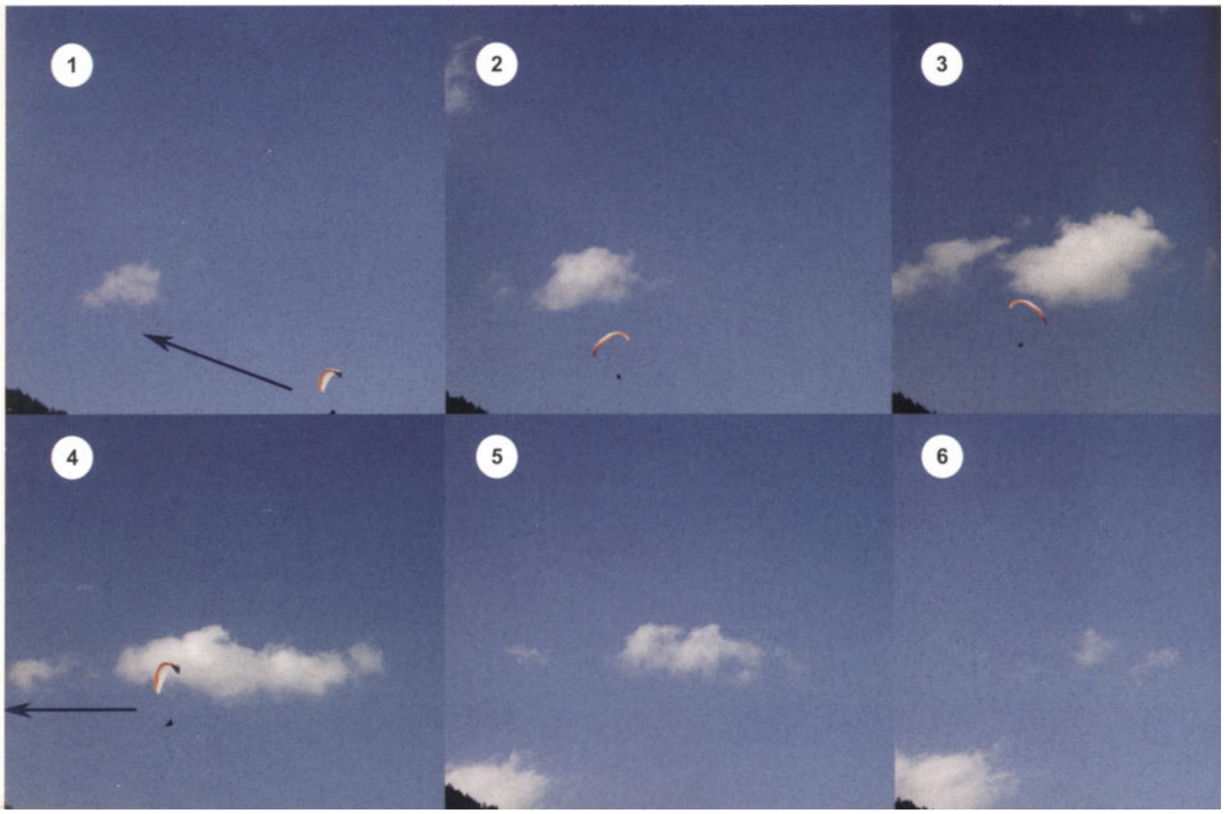


Thermal lifespan

The photo series shows a cumulus cloud indicating the life of a thermal. The wind pushes the warm air towards a triggering ground feature (here it is a forest edge) and it sets off as a thermal. A small cu is formed. The cu grows as the warm-air influx from below increases, and eventually a semblance of a defined cloud base is reached. After a while the cloud begins to dissipate, and later it is completely gone - the entire life span of a thermal made visible. Notice that the cloud looks similar in the forming and the dissipating phase - but flying under it is very different, as a dissipating cloud has only increased descending beneath it. As pilots we want to avoid heading for dissipating clouds and thus we need to observe our surroundings to be able to discern which clouds are forming and which are dissipating.

Hint:
It is very difficult to assess clouds that are still forming. My preferred technique is the following: While thermalling I always watch the clouds in the direction that I'm going. A full circle takes about 15-20 seconds, and every time I have the cloud right in front of me I observe it briefly. After 4-6 looks spanning a few minutes I have a good idea of what the cloud is doing - much better than if I had been watching the cloud continuously during the same time. Don't think that this is easy though; the more clouds surrounding you, the harder it gets to pinpoint the interesting, growing ones!

Hint:
Observe your surrounding continuously whilst flying. Only by doing so you can build a picture which of the cu's around you are building up and which are dissipating. Track their development to get an idea of the life span of the thermals, and which ones have already been active so long that flying to them doesn't make sense.



Picture series 1.48 Six pictures showing the life span of a cumulus cloud. In the first frame the cloud is just beginning to form, from picture 4 it is decaying again. It only pays to head for developing cu's as decaying clouds indicate nothing but increased descending. From the first to the last photo app. 10 minutes went by.


MORE JOY IN FLYING
Yeah man!
This is what makes flying fun!!
A wing concept
for every pilot
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MESCAL
freerider – DHV 1-2
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POISON
biplace – DHV 1-2
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powered paragliding – DULV/DHV
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skywalk GmbH & Co. KG
Bahnhofstraße 110
83224 Grassau
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Wind influence on thermals

When the air is unstable and the sun is strong, good bubbles of warm air form, to rise as thermals. Once they begin rising their path through the air is decided by the wind - the stronger the wind, the more they drift. When we approach a cloud expecting to find lift beneath it we must take this drift into account.

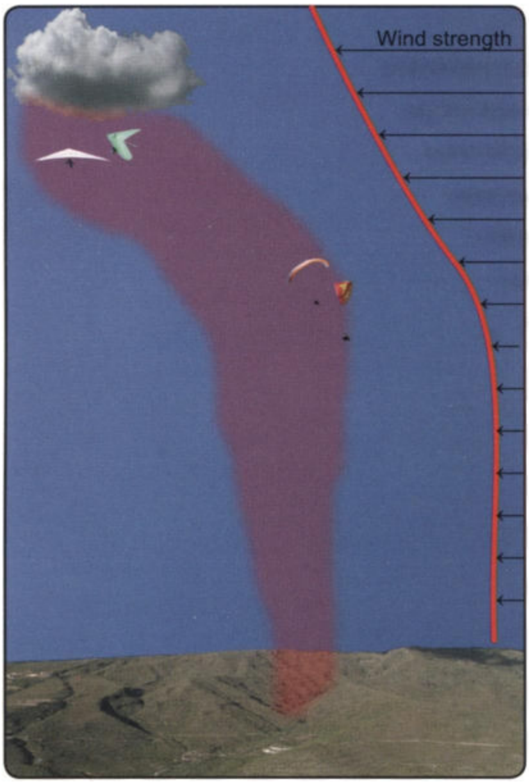


Illustration 1.49
Thermal drift. The arrows on the right show the wind direction and strength - notice the increase with altitude. Low down where the wind is weak there is little drift and the thermal rises almost vertically. Up higher the wind increases and the thermal drifts with it - in this case at the altitude where the paraglider is. To remain in the thermal the pilots must follow the drift towards the right, or they fall out on the windward side.

Picture 1.50 This picture shows how the thermal drift increases with altitude. In the middle we can see a clear drift towards the left.

Large warm air bubbles can only form when they are relatively undisturbed by wind. This is the reason why leeside thermals are often stronger; they form in the lee where they are undisturbed by the wind, and thus trigger later than thermals coming off the windward side.

From wind strengths around 25km/h the warm air is continually disturbed and triggered into rising as undefined bubbles of lift, hardly usable by paraglider and hang gliders at least down low. Up higher the bubbles join into more defined thermals, allowing thermal flights even at strong winds. However getting up there from a winch tow for example is generally rather difficult. Hang gliders being towed up by an ultralight aircraft have a definite advantage here.

Flying in mountain regions at such wind speeds is not recommended. The lee side of crests and ridges will produce very unpleasant and dangerous turbulence.

In the flatlands we may still carry out thermal flights at such windspeeds, because small local lees caused by hills, villages, forests etc. allow the thermals time to form and turn into usable lift. If the ground level wind is strong the thermals often don't trigger off their source but are pushed to more obvious trigger points, like forest edges, rivers, hills or even power lines.

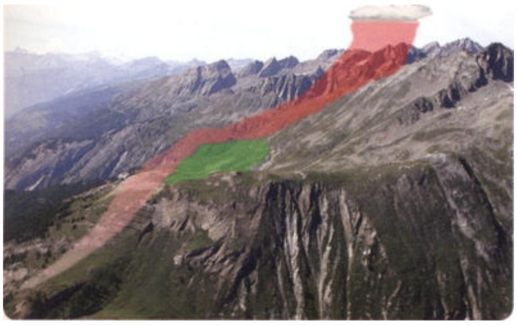
Hint:
If the wind speeds increase dramatically with altitude (more than 20km/h per 1000m) the thermals will be stirred to such an extent that flying for all practical purposes will become impossible. On such days it is better to remain on the ground.

Thermal drift over crests

The next illustration shows the thermal drift over the terrain. Low down the warm air follows the slope in an anabatic flow, as seen in picture 1.5. Over the first crest the thermal is pushed still further right by the wind, note that strong thermals are pushed less than weak ones!

Hint:
The same slope may produce both weak and strong thermals. To avoid the risk of getting blown back into the lee it is best to concentrate on the stronger ones. When thermalling in strong winds it is important to always remain near the windward edge, as dropping out here only causes us to descend back into the thermal, whereas dropping out on the lee side could mean sliding down the backside of the thermal unable to reenter due to lack of ground speed. More on this in chapter 8.

If the plateau behind the first crest has landing options we may opt to try coring even weaker thermals, thereby consciously risking a premature plateau landing.



Picture 1.51 The normal wind- and thermal situation along the terrain when the wind is onto the slope. To avoid dropping out of the thermal when reaching the first crest the pilot must concentrate! Once higher he can allow himself to drift over to the higher ridge and either soar up or continue thermalling.

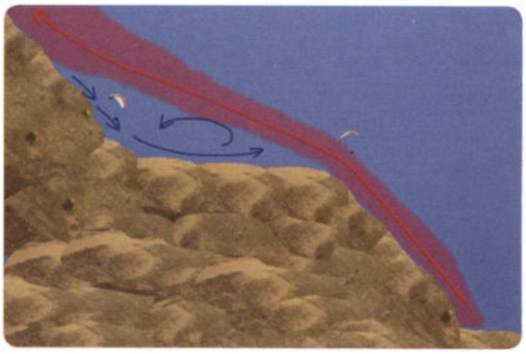


Illustration 1.52 This frame shows the problem from 1.51 even more clearly. The pilot on the right is thermalling near the windward side of the thermal whereas the left pilot tried to push back to the high terrain too early and now has to cope with a plateau landing in turbulent conditions.

Chapter 2: Thermal generators and triggers

I often see pilots searching around for thermals in what I consider unlikely places, and pilots also often ask me why I have flown to a particular spot to search. Whenever the latter happens I have to stop myself from simply saying something like "it looked good". In fact, what makes a specific point in nature look "better" than all the potential locations around it is a complex matter, and coming to a conclusion happens only via numerous deliberations. In the beginning these are all conscious but with experience become increasingly subconscious until we cannot even say what caused us to fly there anymore!

Whilst learning we need to consider the following things:

- Which soil/ground heats well?
- Where would a thermal, coming from that patch of ground, flow taking into consideration the wind and the terrain?

We have learnt that thermals happen because the sun heats the ground, and the ground heats the air above it. Now let us take that one step further.

Albedovalue, a measure for the "heat-ability" of the soil

The albedo value indicates how much of the sun's rays are reflected by a given material. The higher the albedo value, the worse for thermal development because all the energy is reflected and not enough lingers to heat up the soil.

But the albedo value alone isn't the whole story. If the soil is soaked with water, energy must first be spent on evaporation before the heating can get underway. This process uses up a lot of energy, which then isn't available for thermal generation.

Finally a porous soil containing lots of air heats more easily than a more compact one.

Picture 2.1 A very clearly marked thermal trigger point, the saddle above Schnalstal in the Italian Alps. Generally the ridgeline will trigger the thermal (as seen in picture 1.4) but with a bowl like this facing right into the sun the areas right or left, depending on the wind direction, are also very good. In the middle of the bowl we can expect increased descent values.

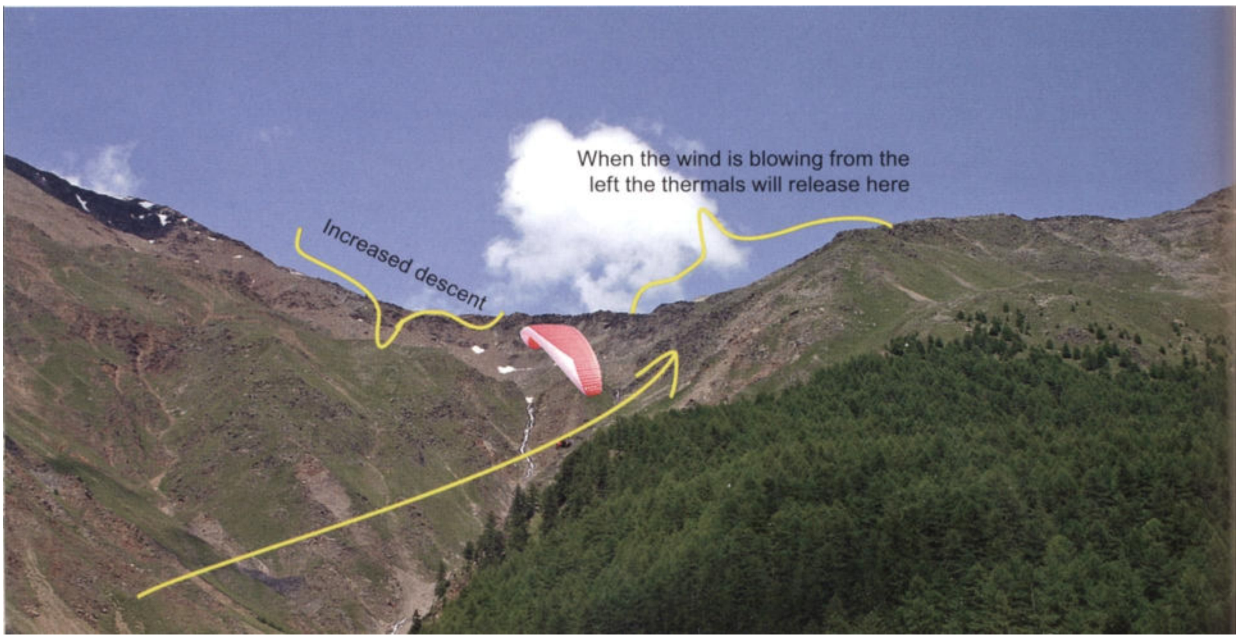


Table 2.2 Albedo values for different soils

Surface	Albedo value
Dry grain fields	Extremely low
Asphalt	Extremely low
Black soil	Very low
Damp sand	Very low
Coniferous forest	Very low
Vegetation-free soil	Low
Gras	Low
Deciduous forest	Low
Desert, water	Medium
Dry sand	High
Snow	Very high

Factors to consider when evaluating the thermal generating properties of any given soil:

• Damp soil absorbs much energy without releasing it again. For a moor to generate thermals we must wait until late in the day, when the surroundings have begun to cool down. The moorland will cool slower and sometimes allow us to linger in light lift over places where we are not accustomed to finding lift.

• Deciduous forest has a relatively low albedo value, but contain much humidity. This makes them less thermally interesting than coniferous forests where there is less humidity stored.

• Any surface oriented perpendicular to the sun rays rays will heat better than surrounding, non-perpendicular surfaces. In the Northern hemisphere this means east slopes in the morning, south slopes around noon and west slopes in the afternoon. Because the sun is higher around noon the south slopes can be shallower (on the Equator they can be horizontal) than the east- and west slopes. In the European winter only steep south-facing cliff faces produce usable thermals.

• Surfaces with a high specific heat capacity (like rocks) take longer to heat, but once

Picture 2.3 Snow's albedo value is very high, and very little energy is absorbed from the sun. Snow is the poorest possible thermal generator.

warm they will continue to produce thermals even during short overcast periods. East facing vertical cliffs are the first to produce thermals in the morning, not because of the specific heat capacity but because they have been facing into the sun for the longest time.

• Desert surfaces and dry sand have high albedo values but are very porous. Further, deserts are often in regions with strong sunlight, and the porosity plus the strength of the sunlight combine to produce strong thermals in desert regions.

• Coniferous forest, and clearings therein, are good thermal generators.

• Wet green fields are no good, but newly harvested they are OK. If there's hay drying in a field it is probably good!

Picture 2.5 A farmer prepares the hay harvest. The pilot has seen this and promptly flies there. The location is good, not only because of the low albedo value of grass fields, but also because the farmer in his tractor triggers all the accumulated hot air with his driving around.

• Grain or potato fields are good. Corn fields only get really good in the autumn

Picture 2.4 Lake Walensee, Switzerland. Lakes do not generate thermals, but neither do wet fields or heaths, except in the evenings when a shallow heath may release the energy saved up during the day. On the mountain in the picture all thermals will originate from the slopes above the lake. On little hills they become short-lived because of it. Would fields surround the mountain instead, thermals could have benefited from the heating of air around it as well, and would have become more reliable.

Picture 2.6 The Parseier Peak in the Inn valley, Austria. The rocky southeast oriented slopes are perfect for generating early thermals. The Atos pilot knows this and flies straight there. He has launched from the Venet, a north-facing launch that is uninteresting at this time of the day.

• Ploughed fields are better than untreated ones.

• And crowded parking lots or industrial expanses are always excellent thermal generators.

Hint:
When a parking lot is full of cars it becomes even better, as more hot air may be trapped among all the parked vehicles. Thermals originating from full parking lots are generally both stronger and wider and thus easier to core.

Hint:
Thermals may come from any surface that is readily heated by the sun. For your mental picture try to imagine walking over the ground where you're flying. Wherever you feel the air getting warmer you can expect thermals to originate, whenever it gets cooler it is less interesting. This means that cool, shady and wet areas will always hinder thermal development.

Picture 2.7 Flying over the official landing at Brauneck, in the German Alps. This parking lot is an excellent thermal generator in spite of its location in the middle of a valley. However the thermal will normally be offset by the valley wind and is often located right above the official landing, to the joy of the students training there. The instructors are less enthusiastic about it...

Thermal development delay

The time that passes between the sun hitting a given surface and the surface releasing the first thermal could be called the thermal development delay. This time differs from surface to surface.

Rocks have long delays but store the energy for a long time; coniferous woodlands and fields have shorter delays but stop working as soon as the sun doesn't hit them anymore.

Shade drawing in from the side triggers thermals, provided the air has been heated sufficiently, but once the thermal has released and risen the show will be over there until the shade is gone again. Depending on the surface, some time will pass before a previously shaded area releases its next thermal after the sun has come out again. Readily heated surfaces will have the next thermal ready in as little as 10 minutes whereas areas consisting of soils with a high specific heat capacity, like rocks, take notably longer.

Picture 2.8 Once the cloud shadow is gone it takes only a couple of minutes before the next thermal is ready.

Thermal trigger points

Warm air, being lighter than cold, has the inherent tendency to rise. However a release impulse is needed to overcome the inertia. The following is a short and incomplete list of possible impulses or triggers:

- Terrain or vegetation changes, like forest edges, ridgelines, uneven slopes
- Temperature changes caused by snow, shade or water
- External factors, like moving objects or even acoustic impulses

Picture 2.9 A perfect thermal generator/trigger. Hopefully the pilot will arrive high enough to take advantage of it. Near the Hallstatter Lake in Austria.

Picture 2.10 An uninterrupted mountain chain, like the Pinzgau, Austria, will release thermals along the entire length. Once up bombing out is almost out of the question.

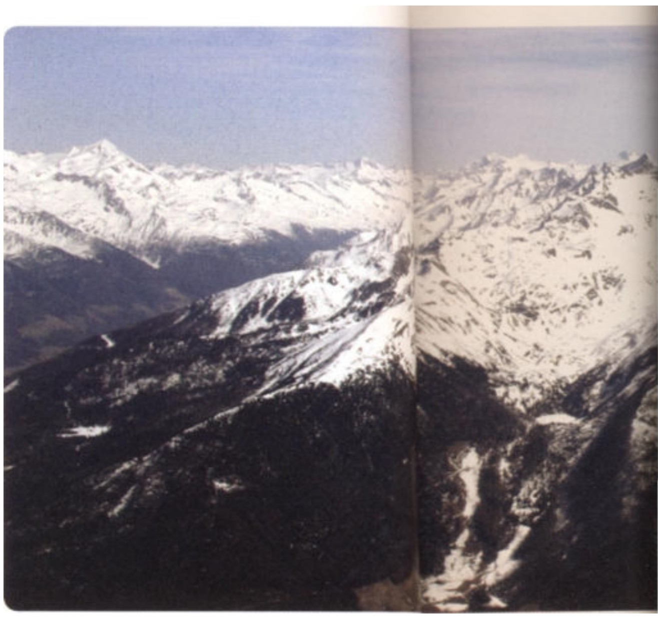
Picture 2.11 Launching from the actual thermal trigger, a little knoll in front of the main peak. The pilot can expect to be climbing right from the beginning. The picture shows the old hang glider ramp at the Helmsattel in Austria.

w

Picture 2.12 When the main peak has a little shoulder in front, this will often be a more reliable trigger than the main peak. In this illustration the points AtoC are the shoulders, and the mountain D has no shoulder. D is the best thermal generator (see arrow), E is the peak above shoulders A to C. If we're high we fly straight towards E, knowing that should it not work we can aim for A to C. Once high in either place the way to D is secured. Picture from Valais, Switzerland.

The most obvious trigger point is always the peak, but the shoulder (if at hand) is no less important! In the Alpine spring the snow line overtakes the shoulders' role.

Picture 2.13 In the Alpine spring the snow line is themostcommon thermal trigger. This photo was taken in March in the Italian Alps, an area where the thermals are very good at this time of the year.



**Further el
mal triggc**

• Forest cleari

Further easily identified thermal triggers

• Forest clearings

Picture 2.14 Such a distinct clearing in the woods is a very good thermal trigger. If the pilot is high he should fly to the crest above but if that fails searching right above the clearing is a good strategy.

• Powerlines. In the mountains these are often located on shoulders (see picture 2.15) and their triggering capacities may be partly explained thereby. But powerlines are also known to trigger thermals in flatlands, where there's no terrain to explain it.

Picture 2.15 The electricity mast is located right on the shoulder and we can expect good thermals to be coming off of it.

Thermal triggers in flatland flying areas

• Large temperature differences, as found on lake- and river shores

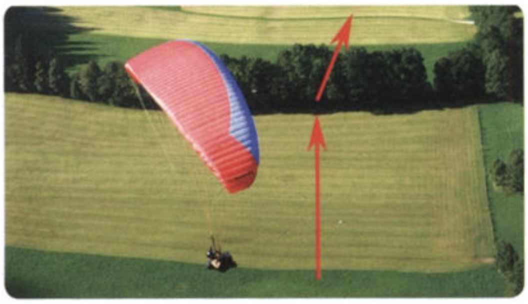
• A forest edge or a tree line

• Small hills - although these are difficult to see from an altitude

• Railroad tracks and roads.

• Active farming machinery, see picture 2.5. Harvesting is very often associated with excellent thermal development.

Picture 2.16 A lake or river shore is a very good thermal trigger. If the wind pushes the heated air towards the shore, the temperature difference will trigger it. Due to the thermal drift the lift will be located over the water.



Picture 2.17 A tree line is easy to see even from high altitude. When the wind blows against the line, even at an angle, the thermals will be triggered.

• Cloud shadow moving over the landscape - but beware! If the cloud is big and the drift slow the shade causes all activity to cease for a while!

Hint:
If the wind is strong such tree lines or forest edges may even be soared until a thermal is released. It is however an "experts only" game, as coring thermals low down in strong drift is very tricky, and the chances of being dumped either in the lee or over unlandable woodlands are high.

Illustration 2.18 The shade from the cu moves over the landscape with the wind. As it progresses it triggers thermals in front of it. The red arrow shows the wind direction, and the pilot can fly with a tailwind from the cloud directly to the new thermal trigged by the cloud shadow.
If the pilot has been flying on the upwind side of the big cloud (left) and the thermal has died, getting across the big shadow can be a challenge, but there's a good chance of getting up again if we can only reach the shadow border, where the next thermal is released.

Hint:
A friend told me how he had once cored a thermal being "pulled" up by a hot air balloon! It was the best thermal of the otherwise unspectacular day!

***Picture 2.19** De Aar, South Africa. It looked like a perfect day - but the cloud base was only 800AGL and centring from low altitudes turned out to be difficult. It took four tows to finally get up.*

***Illustration 2.20** The clouds indicate where the thermals are to be found. On this day the distance between thermals was unusually far, and the cloud base was not correspondingly high - which meant that we generally arrived really low in the next thermal! Industrial areas and villages were the best sources.*

***Picture 2.21** Ahh, to be towed right up into the thermal and then release when the vario has been screaming for a few seconds...*

Cloud shadow as release impulse

By Volker Schwaniz

As soon as the ground is getting cloud covered, the surface begins to cool down. Due to this effect the temperature difference between shady and sunny is quite noticeable, and as we have seen before, temperature differences are reliable thermal triggers. Whether the thermal triggers upwind or downwind from the shade (cloud) is decided by the forward speed of the shady field, i.e. the cloud speed and thus the wind at cloud altitude in comparison to the wind strength and direction at ground level.

In the mountains the thermal will normally be triggered to the upwind side of the cloud shade. The cool air from the cloud shade soon rolls down the mountainside in an anabatic flow and pushes against the still active catabatic flow on the windward side of the cloud shadow, causing a very strong triggering impulse. This can be observed at slope launches susceptible to overshading; there's often a tailwind even if everyone is climbing happily only metres out from the slope.

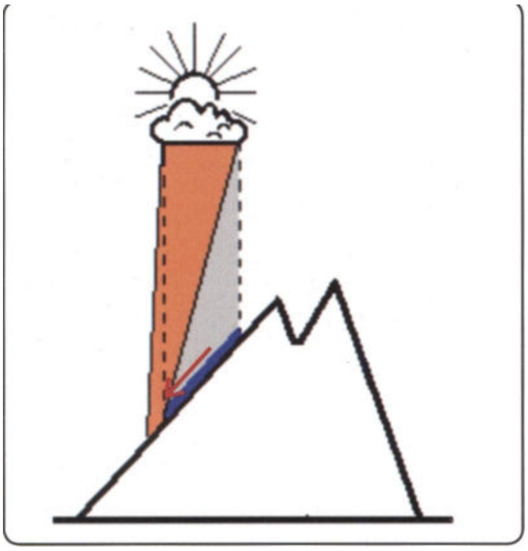


Illustration 2.22 Cloud triggering of thermals in mountains often happens on the windward side of the cloud shadow.

Hint:
If the launch is getting cloud covered due to cumulus development over the launch mountain while the lower slopes are still in the sun it pays to get off quickly, before the adiabatic flow sets in, causing a tailwind.

In the flatlands the cloud shadow triggers the next thermal on the downwind side of the cloud, see illustration 2.23. This is caused by the generally stronger wind high up causing the clouds to move faster than the winds at ground level can displace the warm air. The briskly moving cloud shadow thus "pushes beneath" the warm air and triggers the thermal, which in turn is offset by the wind.

Wind

Wind

Illustration 2.23 Flatland cloud shadow as trigger. The thermals are triggered on the downwind side of the cloud shadow.

Hint:
In the flatlands cloud shadows should only be used as thermal indicators when we have a comfortable altitude margin, as coring below 300-400m is often difficult.

Hint:
When towing it pays to look out for approaching cloud shadow, as these increase our chances of hooking right into a good thermal, provided we get the timing right.

Thermal alignment with the wind

By Volker Schwaniz

Downwind of strong thermals we often encounter further thermals. They form in irregular intervals and are almost perfectly aligned with the wind. They are easy to see from the cumulus formation that they cause, which differs from cloud streets because they are further apart. Another difference is that neither particular weather situation is needed, nor a specific wind strength. Whenever there's thermals and wind, a certain alignment can be observed!

The precise reason for this is not entirely understood, but it is assumed that the peripheral, weaker parts of the mother thermal are offset more by the wind and drift further downwind, where they meet and join forces with new wafts of lift coming from beneath. Long rows of usable lift are generated in this manner, and they may live for as long as 30 minutes longer than the actual mother thermal.

Notice that the nature of the soil downwind of the mother thermal influences the extent of the phenomenon. Moist forest areas, wetlands or water inhibit it or stop it completely.

There's another hypothesis that attempts to explain the thermal alignment. It deals with the fact that the high-level winds are known to be brought into oscillations by flowing over strong thermals/well-formed cumulus clouds, setting up a wave pattern leeward of the mother thermal (see drawing 2.24).

In the upwardly moving sections of this wave pattern the airmass is less stable and more prone to thermal development. Glider pilots have been known to use cumulus waves to fly over strong cumulus clouds.

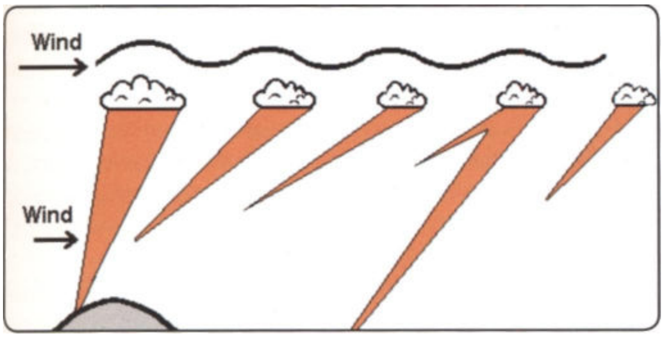


Illustration 2.24 Downwind of strong thermal sources we often encounter further thermals and not only dissolving remains of the first, strong thermal.

Hint:
Inexperienced pilots often assume that the smaller cu's leeward of a big cloud are just dissolving remains of the big one, producing only increased descent. This is often not the case! Leeward of pulsating thermal sources we often encounter further, weaker lift, it follows that it pays to fly directly downwind from a good thermal, especially in the flats.

Hint:
Updraughts (thermals) and downdraughts go together like RedBull and vodka, and just as the thermals tend to align with the wind the downdraughts will do the same. This means that the best escape route from widespread descent is perpendicular to the wind direction (provided the sink isn't caused by a lee zone).

Hint:
Thermal alignment due to wind does not depend on cloud condensation. This means that it is also found on blue days, albeit less visible.

Two different route choices in a wide valley

As soon as the pilot decides to abandon one thermal and fly to the next, we can consider it XC flying. Here we describe two different choices:

First choice

The pilot flies from mountain shoulder to mountain shoulder (see illustration below).

Advantages are that he always arrives high enough to make it to the next west flank, where he can expect thermals to be coming up. Should no thermals be found he can glide down to land in the wide valley where he has plenty of landing options, instead of being forced into the high valley between the two ridges.

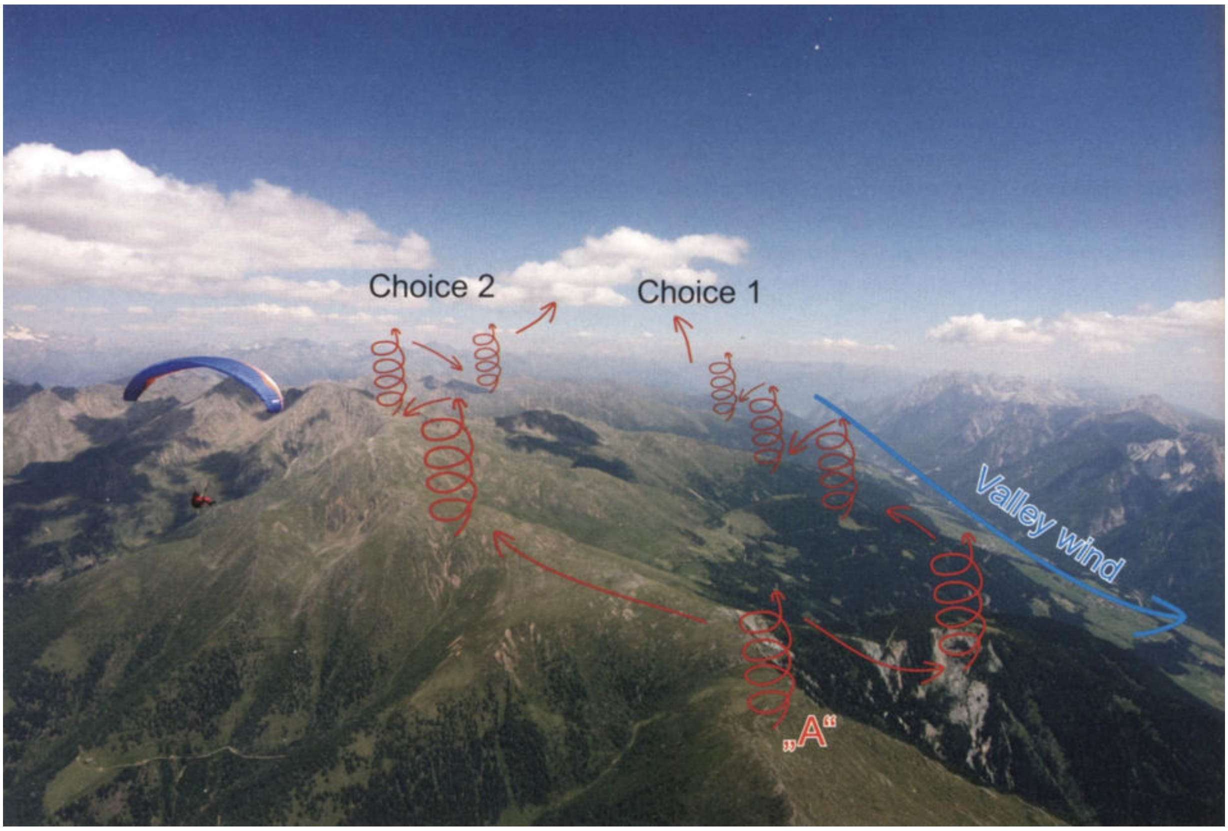
Disadvantage is that he soon finds himselve under the influence of the valley wind system, where the mere strength of the wind disturbs the thermals and makes them difficult to use. This can often make it hard to get up high again.

Second choice

The pilot makes maximum altitude at "A", then follows the terrain up along the flanks of the main summit until he is above the main ridge.

Advantage is that, provided cloud base is high enough, he can remain above the main peaks, undisturbed by valley winds and with strong, consistent climbs. Our overall speed can be very good up here! Besides, the view is better than along the shoulders out near to the valley floor!

Disadvantages occur when he doesn't make it to the next climb above the ridge - then he could be looking either at a landing up high, or in a narrow side valley, or at least a long detour around the next perpendicular ridge. Even if this detour works it takes a long time, also because he arrives lower than he would have, had he come straight there, and must thus battle it out even lower in the valley wind to get back up high.



Preliminary conclusion:

For the XC beginner it generally pays to remain above the foothills, or what we have called the "shoulders". The high route over the main ridge is only fast if there's no risk of not making it to the next thermal - otherwise there are large detours on the menu!

Picture 2.26 Pinzgau, Austria. When the cloud base is very high, as in this picture, we remain above the main ridge. If against all odds we should fall out it will probably be right onto one of the shoulders seen protruding from the main ridge into the valley, and the chances of making it back up will be good. A further advantage is that we will not need to go into the narrow gullies between the mountains.

The Alps abound with these large E-W oriented valleys, all very well suited for flying: In Austria we have the famous Pinzgau and the eastern end of the Pustertal, we have the Drautal (Greifenburg), the Inntal (from Innsbruck to Arlberg), and the Ennstal with Schladming and Werfenweng.

In Italy we find the Ahrntal in Alto Adige Southtirol) and Feltre in the south east. Switzerland has the Engadin and the Valais, and all these valleys are renowned for their excellent flying conditions.

Picture 2.25 (left side)
View of a wide, E-W oriented valley. On the left a massive, unbroken chain with wooded foothills reaching into the main valley, with narrow valleys between them. Two options for flying the ridge present themselves: Either over the trigger shoulders near to the main valley or above the main peaks of the chain. In both cases we approach point "A" first to gain the altitude we need to continue. The photo shows the Pustertal, Italian/ Austrian Alps.

Picture 2.27 A similar chain to the one in 2.26, this time the Goms in Valais, Switzerland. This particular stretch of mountainscape is renowned for fast, reliable flying. The picture was taken from cloud base, and the marked places all had (as indeed they generally do) very good thermals coming off of them. On this day the cloud base is insufficient to fly the high-alpine route as indicated along the "B" arrow.

Picture 2.28 Another shot from the Pinzgau valley in Austria. This is really one of the finest flying arenas in Central Europe, and scores of pilots fly here, enjoying the strong, spacious thermals and the modest valley winds, along with the presence of landing options everywhere.
This day was actually not as good as the photo seems to indicate - the atmosphere was too unstable and the clouds overdeveloped in the early afternoon, shutting down all thermal activity.

The A.I.R. Atos „Cage“ with fairing and almost unbelievable glide ratio. Picture: Willi Tacke / Flying Pages.

Chapter 3 Thermal related Issues

Turbulence

Turbulence is the pilots' natural enemy. The most well-known cause of turbulence is the lee, and I doubt it that anyone enjoys flying in a strong lee. But since the air is rarely still it is a fact of life that we as pilots must get to grips with turbulence - avoid it as much as possible, but accept it where it is inevitable.

Leeside turbulence on a large scale may be found behind mountains, on a smaller scale behind other obstacles like trees and houses. "Behind" in this sense is always "on the lee side".

Wind shears and even thermals are other causes of turbulence, as well as other wings passing upwind. Thermals bumping into inversion layers also cause turbulence. Generally, light winds and weak thermals mean less turbulence whereas strong winds and strong thermals cause strong, sometimes extreme turbulence.

In strong turbulence the paraglider may collapse and the hang glider may tuck. In extreme cases the pilot may crash due to these turbulence-induced disturbances. A mental picture could be the already mentioned wave surfer, riding the crest of a wave

Illustration 3.1 Strong thermals cause strong turbulence. If the pilot falls out of the side of the thermal the wing may dive very aggressively. It is not dissimilar to a surfer falling off the lip of a wave.

Picture 3.2 The wingtip rotor (vortex) made visible in a wind tunnel. Such a rotor is present behind any wing moving through air. The bigger and heavier a wing is, the stronger the vortex. Behind large airplanes the vortex may linger for several minutes and still be strong enough to cause a paraglider to collapse. Picture courtesy of Manfred Kistler, Skywalk.

- if he falls off he will be washed through the turbulent waters. But the air is invisible, so we need to know the causes of turbulence to be able to avoid it; we cannot just look for it like the surfer can.

When watching airplanes landing, we can often observe the wingtip rotors (page 76). The vortex rings may be visible for several minutes after the plane has landed - but such rings may also linger in open air long after a plane has passed.

A large, heavy transport airplane creates extreme vortex rings and any hang glider or paraglider flying into them will be in for a big surprise!

As paraglider pilots we are familiar with wingtip turbulence from passing behind other pilots, especially when soaring small ridges with a group of other pilots.

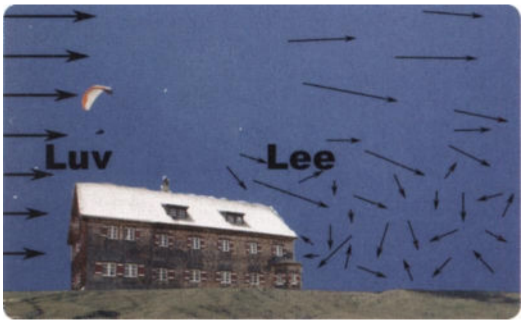


Illustration 3.3 We encounter lee rotors "behind" anything pointing into the air flow. Here is shown how the air may move on the lee side of a house. The terms "in front of" and "behind" are linked to the wind direction.

The bigger the obstacle the greater the turbulence, and the stronger the wind the stronger the turbulence. With little obstacles like trees or rows of trees we should aim to land at least 100m downwind - if the obstacle is a house it is better to land off to either side.

Info box

Windward - the side facing into the wind. This is where we preferably fly

Leeward - the side facing away from the wind. We normally try to avoid flying here

Laminar flow - An undisturbed flow, comparable with water flowing smoothly out of a tap

Turbulent flow - A wild, unorganised flow comparable with the tap turned up to max

Picture 3.4 Lee made visible. Notice that it is not turbulent on the lee side, however the descent is greatly increased.

Turbulence behind mountains

The strength of the turbulence depends on the terrain. Gentle slopes cause less turbulence than steep rock faces. If the wind is strong, the turbulence behind steep cliffs may stretch for several kilometres, but in flyable winds we use about one km as a rule of thumb. The area closer to the obstacle is worse than further away.

H i 4? \.'SI Bp' V'M ∩ 51' 1 uH

Illustration 3.5 Behind gentle sloping peaks the turbulence may be all but nonexistent, but there will still be increased descent. This hang glider should stay on the windward side.

Illustration 3.6 A flight along the famous „3 Peaks" in the Italian Dolomites. Behind such pointed, jagged peaks the turbulence may become dangerously strong, and we should strive to remain well away from them. This pilot should fly even further left.

Turbulence behind slope edges

Behind slope edges the strength of the turbulence depends on the inclination of the slope, the shape of the edge and the wind speed. The illustration shows a cross section through a typical soaring ridge, with the rotors drawn in. Pilots often top land on such ridges, so here are a few tips:

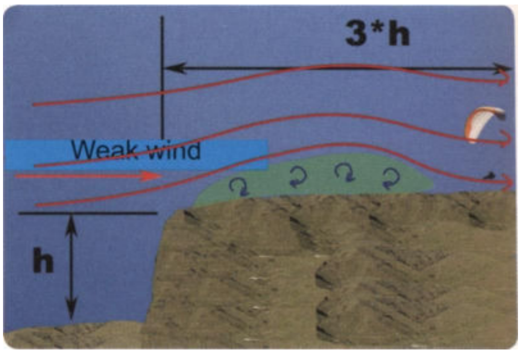


Illustration 3.7 If the slope is steep, and the edge sharp, a rotor area will set itself up right behind the edge (marked with green). With moderate winds it will normally be possible to land 3xh downwind from the edge.

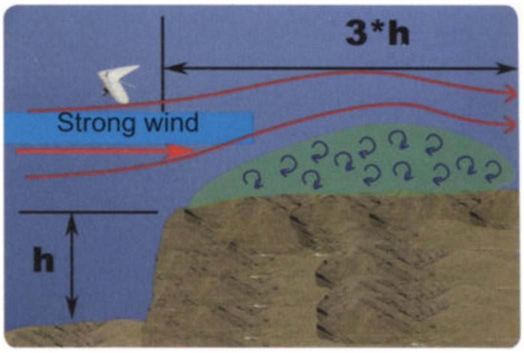


Illustration 3.8 With stronger winds the turbulent area increases dramatically in size, to well beyond "3xh". Top landing will now be dangerous almost regardless of the distance from the edge.

Many mountain launches look similar to the one in picture 3.9. Sites in the Alps that come to mind are, Aspres in France, Casteluccio, Meduno and Feltre in Italy. These flying sites are perfect for learning how to do top landings.

General points for top landing:

- Weak winds mean less turbulence = top landing is OK

- The steeper the slope in front of the edge, the further the rotor area stretches downwind. As no one can exactly know HOW far, it is generally better not to top land behind steep slopes.

- If the slope has thermals coming up we need to be extreme careful. If a thermal releases at the wrong time, and sucks in the air from all sides (even from the flat top where we are trying to land) things can get ugly. It could be a case of tailwind AND turbulence/rotor all at once.

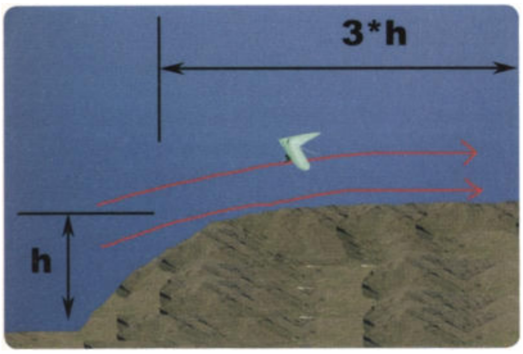


***Illustration 3.9** If the transition from slope/mountain side to plateau/mountain top is gentle there may be no rotor formation at all. These are the soaring ridges where paraglider pilots can really play! Top landing with no stress is guaranteed, see also picture 10.27.*

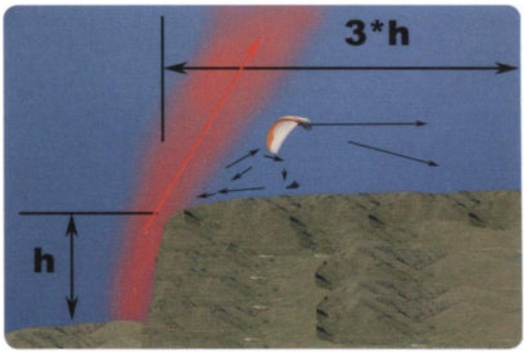


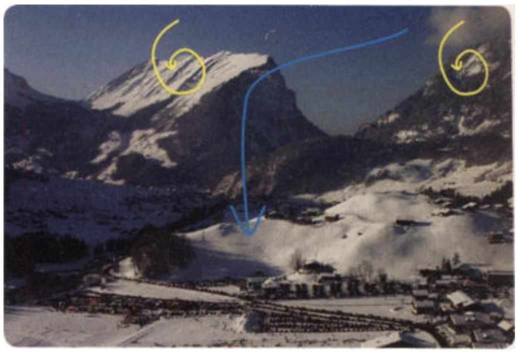
***Illustration 3.10** If the slope has thermals flowing up it is better to not top land. The thermals suck in air from all over causing tailwind on top while the thermal drifts past.*

There may be strong turbulences around high and sharp peaks. Chamonix, France.

Horizontal rotors

Rotors are not exclusively vertical air movements. If the wind flows past obstacles there will be horizontal rotors behind the obstacles.

***Picture 3.11** A mountain with a horizontal rotor, drawn in yellow. The wind is not strong enough to flow over the mountain but flows around it instead. We must expect turbulence on the lee side, just like in the next picture.*



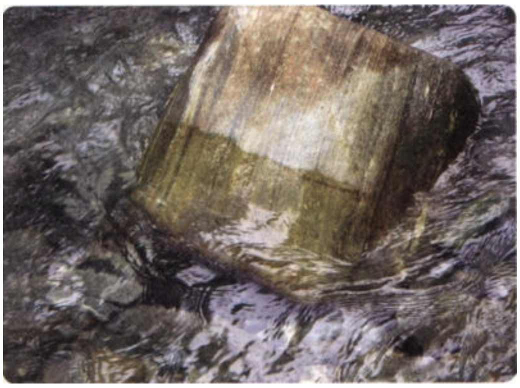
***Picture 3.12** As the valley wind blows through this venturi it increases quite dramatically in strength. It is still not strong enough to flow over the top of the mountains but will form horizontal rotors in the places indicated by the arrows. The picture shows the Diedamskopf, Austria.*

Hint:
Rotors and turbulence are mostly invisible, but by learning to visualise the moving air we may also learn to anticipate them and avoid dangerous areas.

Picture: Kurt Eder. Flying in the South Tyrol Province, Italy.

Using water to visualise rotor formation

Water and air behave in a similar manner when flowing around obstacles. This means that the observant pilot may learn about the invisible movement of the air by watching flowing water! Just as water flows around, and sometimes over, obstacles, so does air. By watching flowing water we can thus see exactly what is going on in the lee of mountains, behind valley constrictions, over the top of ridges etc. In the next three pictures the rocks symbolise mountains.

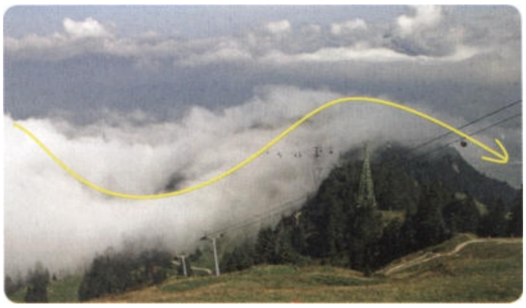


***Picture 3.13** The water is flowing from left to right. If the rock had been a hill the centre would have been good for soaring, but closer to the sides the water is flowing sideways instead of up the slope. This is exactly what we observe when soaring - the best lift is found at the middle of the hill. Due to only moderate flow speeds there is hardly any turbulence behind the "hill".*

Hint:
Use the local brook to learn about the effect of slow and fast flows, of sharp versus rounded edges. Where are the rotors? How far "downwind" do they stretch?

***Picture 3.14** A fast flowing mountain stream. Possibly soarable on the windward side of the rock, behind the rock we can see the "rotors" extending to approximately 5 times the height of the obstacle. Once past this area the water flow is laminar again.*

***Picture 3.15** The water is flowing down the "lee" of a rock. Flow is fast and laminar. As it hits the bottom behind it turns very turbulent. It is comparable to a rounded-top mountain where the pilot may find himself in strong sink, only to encounter extreme turbulence right above the valley floor.*



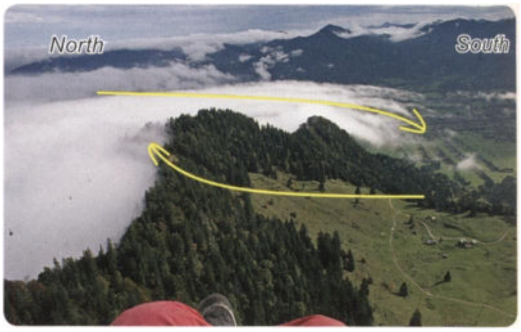
***Picture 3.16** In this photo the cloud formation shows the air movement. The air flows in the same manner on days when there's no cloud to make it visible. Picture from Garland by Brauneck (D).*

The examples are only a small peace of the lessons that may be learned from observing flowing water. Further examples on page 187.

Turbulence caused by wind shears

We call it wind shear when the direction and/or speed suddenly change at a particular altitude. The most common wind shear in the Alps is when the valley wind and the meteorological wind higher up are coming from different directions. The strength and extension of the turbulence caused by such wind shears depend on the wind velocity. Most of the times it is only noticeable as a light shaking but in extreme cases, where two strong winds meet, it can be quite rough.

Wind shears are common in connection with inversions because the wind direction is often different below and above an inversion.



***Picture 3.16** The picture shows a beautiful wind shear situation. The fog is being pushed against the ridge by the valley breeze but the wind is actually coming from the south (arrow). The south side was just soarable up until ridge height, where some turbulence announced that I had entered the realm of the valley wind coming from the north.*

Hint:
Inversions not only limit air movement vertically, they also influence horizontal air movement. It is not uncommon to experience a strong valley wind whilst the mountain top has no wind at all. This is one of several reasons why the speed bar should ALWAYS be mounted before each flight - you never know when you might need it!

Picture 3.17
The pilot is just about to descent into the very cold low-level air mass, often called a ground inversion. At an altitude we had 15km/h from the south, whilst the wind at ground level was 10km/h from the north. The wind shear was nonetheless unspectacular.

Windward and lee thermals

When flying in the mountains it is important to know where the wind is coming from, particularly when using thermals.

Normally we fly on the windward side, and if there's no wind we aim for the sunny slopes.

- On no-wind days the thermals are easy to centre; they don't get torn apart by the wind and they don't drift

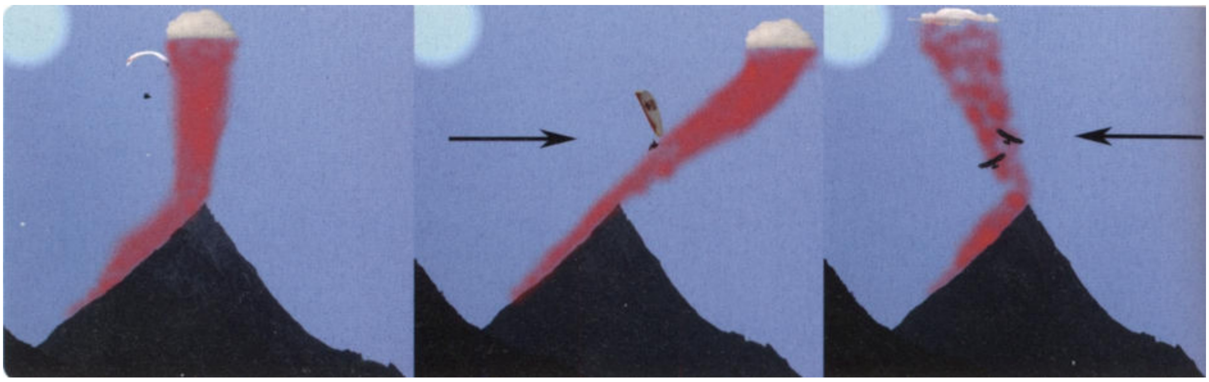
- Windward side thermals are almost equally nice as long as the wind remains weak

- Lee thermals are generally turbulent and thus best avoided

Experience:
Once while flying the Laber near Oberammergau/Germany I went into the well-known lee on the south side of the ridge. I was descending with a steady -9m/s and thinking I would surely have to land in the Ettal monastery when I hit the thermal coming off this monastery - from there I climbed out with a steady 6m/s thermal! This means that I went from -9m/s to +6m/s in a real close vicinity - a difference of 15m/s (3000ft/min) or 54km/h!

Since then I have always avoided getting low south of the Laber!

Picture 3.19 Lee thermal development in Pustertal, Sillian/Austria. We recognise the situation by the big clouds being pushed into the valley from their point of origin on the higher slopes. The day was flyable, as the thermals coming up the face of the mountain were strong enough to override the wind from behind and the launch thus had wind coming up it, but it was turbulent and difficult flying.



3.18 Thermal formation in calm air ***thermal coming off the windward side*** ***thermal coming off the lee side***

Picture 3.20 Goms, Valais/Switzerland. On this day the wind was far too strong for flying. Compare the cloud formation to the picture on the previous page.

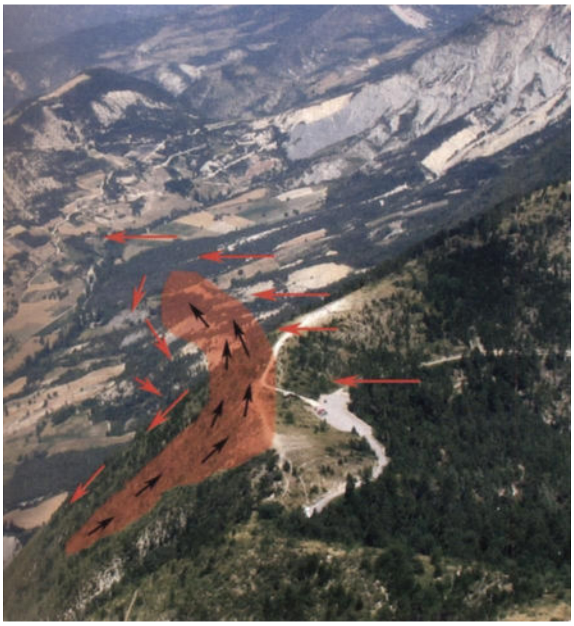
Lee thermals, in the Alps are either on the south side of ridges near the northern boundary or in the lee of local valley wind systems. In the southern Alps the wind is generally local and south, since the mountains suck in so much air from the flatlands that the wind on the sunny south-facing slopes is almost always on. This means nice windward-side thermals!

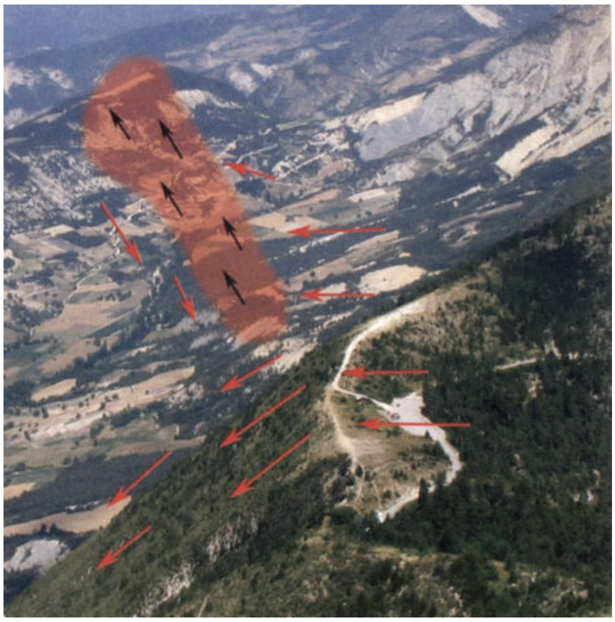
By strong winds lee flying must be avoided altogether. It can be extremely turbulent and dangerous.

Standing on launch it is not always clear if the wind we're feeling coming up the face is the "real" macrometeorological wind or just a thermal passing through, see illustration 3.21.

As a rule of thumb we can stipulate that in "real" winds of up to 10km/h it is possible to use the thermal wind coming up the face to launch into, regardless of the wind direction. The thermals will generally not be too turbulent. By stronger winds the leesides should be avoided altogether.

Picture 3.21 The sun is shining from the left (west, afternoon) but the "real" wind is coming from the right (east). The sun causes big, strong thermals to flow up the west face, and it is easy to assume that all is well if we are not careful. But by watching the wind sock for a bit longer the real wind direction should become apparent and warn us that we're subject to lee thermal conditions. St. Andre les Alpes, France.





Lee - flyable or not?

The road to heaven is paved with good intentions; and one of these is to not fly in lee. However, if we don't find any lift on the windward side, maybe we'll get lucky over on the leeward side?

To do this in relative safety we must understand that lee isn't just lee. Illustration 3.22 depicts a lee situation on a stable day. It could be an autumn day in the north Alps, with high pressure and a strong inversion. The temperature hardly decreases with altitude, in this example only about 1 degree per 1000m, or a temperature gradient (see chapter 9) of 0,1°C/100m.

If the wind is on the face of the mountain it may still be soarable, and the airmass being pushed up over the mountain will still cool down dry-adiabatically, i.e. with 1 degree/ 100m (371000ft). Once the air mass reaches the top, parts of it will be a 9°C colder than the surrounding air, and very much heavier. On the lee side of the mountain the cold, dense air rushes violently back down, causing extreme turbulence on its way. Flying here is not an option, even for pro's.

To illustrate the violence of such a leeside air movement we only need to consider that thermals begin to rise by temperature differences of as little as 2°C - a thermal stemming from a temperature difference of 9°C would be very extreme indeed, probably showing climb rates well beyond 20m/s.

Illustration 3.23
The same mountain, now surrounded by extremely unstable air where the temperature decreases dramatically with altitude. Again, air is being pushed up over the mountain by the wind and getting chilled dry-adiabatically - but this time the temperature decrease just matches that of the surrounding air since the surrounding air is 11 degrees at ridge level, and the rising airmass has been cooled down to 10 degrees on its way up. It will still sink back down on the lee side, but with the low difference in temperature the movement wtH be much more benign. Anyone flying into this lee still needs to fly actively, but it is fully feasible and survivable, as opposed to the previous situation.

Both illustrations assume weak winds and are consciously drawn more extreme than reality would normally be, but the example serves the purpose of explaining the differences between lee flying on stable and unstable days.

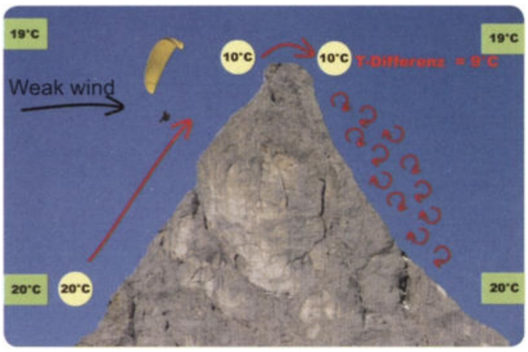


Illustration 3.22 Stable conditions, the temperatures in the valley and around the peaks are almost equal. The airmass being pushed over the ridge by the wind is adiabatically chilled to a temperature well lower than the surrounding air. On the lee side the superchilled, dense air rushes down very violently.

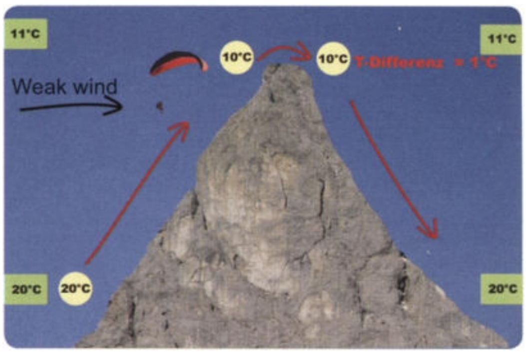


Illustration 3.23 Same mountain, now in unstable conditions. The airmass being pushed over the mountain decreases 1 °C/100m in temperature just as it did in the previous example, but this time the surrounding air is cooling down almost as much with the increasing altitude. The turbulence on the lee side remains within flyable limits.

The examples dealt with the turbulence caused by the downrush of cold, dense air due to pressure differences. The turbulence caused by the wind flowing over the obstacle adds to the complexity of the picture but again we can assume that it is proportional to the wind strength.

Hint:
I consider leeside flying in moderate winds and unstable conditions to be fully doable by experienced pilots, but I personally still seek to avoid it. If i see that leeside flying is inevitable on a cross country flight, I try to balance the risks with the possible rewards. Is the wind really not too strong? Is the air-mass unstable? If I can say yes to these two, and there are emergency landings available I may decide to do it - but the landings are important because if I don't find anything I'll be on the ground soon due to the increased descent in the lee.

Waves and flying in them

Wave flying is really something that is best left to the sailplanes. Reichmann (see the literary references in the back of this book) has described wave flying in detail and reveals that sailplanes have reached altitudes of well over 10.000m in waves, flying at wind speeds of more than 100km/h (54kn)!

However some waves, appearing at far more reasonable wind strengths, CAN actually be flown by hang- and even paragliders.

Picture 3.24 *Evenly spaced and -shaped, the lenticular clouds are a sure sign of wave formation. They also indicate wind speeds way beyond what we normally should be flying in.*

Research into the formation of wave clouds has revealed that some or all of the following conditions are needed for waves to form:

Landscape prerequisites:

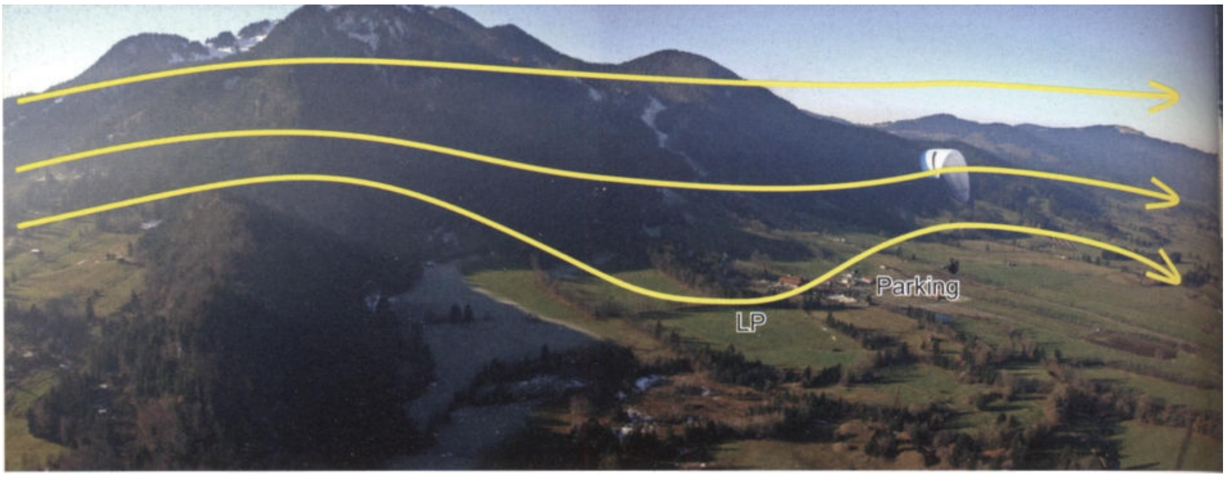
The lee side of the lee-triggering ridge should be steep
The entire mountain should be smooth
The ridge should be long to ensure that the air doesn't flow around instead of over
The ridge should be oriented perpendicular to the wind
Downwind of the primary wave trigger, at a distance matching the wave amplitude, a secondary ridge should be found

Weather prerequisites:

Stable air mass - thermal turbulence disrupts the wave formation
Wind strength at least 30km/h (16kn)
The wind direction should remain uniform all the way up to the top of the stable air mass
The wind speed should increase with altitude

In the weather forecasts for glider pilots the meteorologists frequently state things like "winds insufficient for wave formation" or "wave conditions setting up on the north side of the Alps"; when the latter is the case we should leave the air to the sailplanes and stay at home!

But a few waves, for example the so-called "Thuringer wave" appear at wind speeds low enough for them to be flyable by us, and Chrigel Maurer from Switzerland flew a short XC in a wave in 2004, see www.shv-fsvl.ch under "archive". The story is pretty amazing, as Chrigel was getting ground speeds in excess of 100km/h (54kn) during his flight.



Picture 3.25 Wave next to the Brauneck in the German Alps. The little hill on the left triggers the wave, which sets up right over the Brauneck parking site. It happens by south winds ofapp. 25-30km/h on stable days.

Experience:
I have flown in wave at my own home site, the Brauneck. Most of the conditions from the previous page were fulfilled in that the air was stable and the wind was around 30km/h. The wave trigger was the little 150m high hill SE of the Brauneck, and the wave set up 400-800m downwind. We were all flying right above the valley parking in smooth gentle lift of app. 1m/s. The landing, right beneath the wave, was slightly turbulent.

Conversion table see page 21.

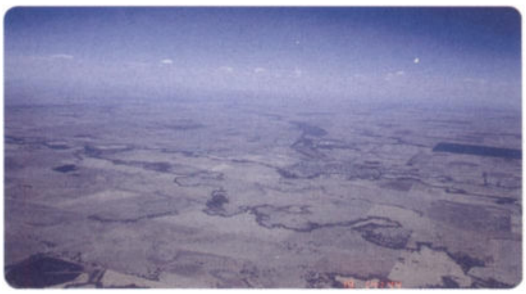
Blue thermals / Clear air thermals

Blue thermals are just thermals without cumulus clouds to top them. Blue days are days when the air is too dry for cu's to form, and there is an inversion somewhere beneath the condensation point stopping the thermals before they reach their condensation level (see chapter 9). The condensation level is the altitude where a thermal reaches a relative humidity of 100% and the cumulus begins to form - cloud base is always at condensation level.

In desert regions the inversion can be very high and still the day remains blue - this is due to the extremely dry air found here.

Experience: ,
I have flown one of my most memorable XC flights on a blue day. I had good climbs of around 5m/s and large, well-mannered thermals. There was no risk of overdevelopment, no clouds disturbing the thermal formation - a great day. Since there were no clouds I could always fly to the best thermal sources without worrying about clouds stopping the thermals before I got there.

It is obviously harder to locate thermals on blue days when no cu's show us where they are. On such days we must base our route decisions on the terrain and simply aim for likely thermal sources and triggers, or we must watch for other hints. Birds, dust, grass, butterflies or even pollen are good markers, as are other pilots. Blue thermals are as diverse as normal thermals; they may be big or small, strong or weak, smooth or turbulent.



Picture 3.26 Blue day in Australia. The clouds are app. 100km away.

Porterville, South Africa. XC flying (for most pilots) over flatlands on blue days is even more difficult.

Hint:
Many flying areas are very lonely to fly. I have friends in Australia who always fly along roads so as to avoid landing too far away from civilisation.

Hint:
There's no reason to think that a blue day is less turbulent than a cloudy day. Blue thermals come in all shapes, strengths and sizes.

Magic air / Reverse thermals

When the sun begins to get low and one side of the valley is already in shade we sometimes get to experience one of the greatest phenomenons of free flight. In English we call it "magic air" because it feels so truly magic - but first things first, here's the explanation:

As the air cools down over the shady slopes of the valley a catabatic flow down the slopes sets in. This cool air pushes under the warmer air on the valley floor, triggering it. This may happen some time during the afternoon and is the first stage of the Magic Air phenomenon. The thermals are offset towards the still sunny side of the valley.

The sunny upper slopes of the still sunny sides are producing their last thermals at this time - soon these parts will also be in the shade, and the catabatic flow sets in on this side as well. The two air masses now meet at the valley bottom, and since there's nowhere to escape to, the air begins to rise from the middle of the valley - the second stage of the Magic Air is in place. Thus, it begins on the sunny side of the valley and gradually moves into the middle as both slopes fall into the shade. The climb rates are not high (mostly) but the lift area is big and gentle (mostly).

To experience this we must try to remain airborne in the last real thermals of the day; only when these finally stop do we glide straight for the middle of the valley. The higher the mountains around are, the better the chances of magic air.

Magic air occasionally even produces cumulus clouds, very feeble things appearing over the valley late in the afternoon and into the evening. It is also responsible for many extra XC kilometres flown late in the day and therewith an important thing to know and understand if we wish to go far.

Hint:
Magic air can also be found over the sea. I have once experienced this in Monaco, where the cold air was flowing down the mountain around sunset, triggering a very smooth and gentle thermal right from the shoreline, allowing me another half hour flying over the water - fantastic!

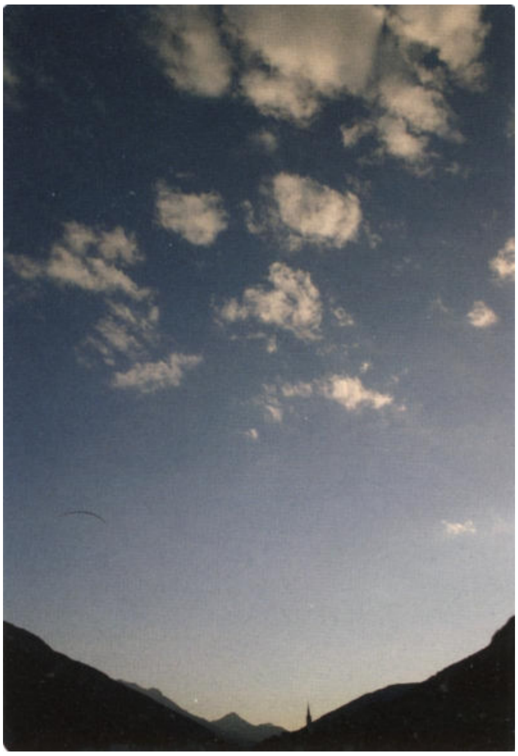
Picture 3.27 It is soon time for some Magic Air flying. The high west-facing slopes are just releasing their last thermals and the east-facing slope is in deep shade, with cold air flowing down from it.

Picture 3.28 By now both sides of the valley are in the shade and there's cool air flowing down from both sides. It meets in the middle of the valley and rises gently. The hang glider pilot has noticed it and heads out with maximum altitude.

Picture 3.29 Magic spring air in Isar Valley, Germany. The relatively healthy-looking cu's indicate strong lift in the middle of the valley.

Experience:
I once finished an XC flight with an extra 30km flown solely in magic air over the valley floor. It was the first time I had experienced stronger, somewhat turbulent magic air, and this was only the case down low. Up high it was as gentle as ever.

Picture 3.30 Evening launch to catch Magic Air.



Picture 3.31 The last wisps of magic-air caused cumulus clouds. The wisps may help us locate the exclusive lift.

Picture 3.32 The best evening launches are high, high enough to allow us to connect with the magic air releasing from the valley floor.

Convergence

When two air masses meet there's nowhere for the air to go, except up. We call this phenomenon "convergence" because the air masses converge to create bands of lift that we may exploit. Flying convergence lines is great fun - generally not very strong, but mellow and reliable. Sometimes a convergence line may allow us to cross an entire valley without loosing any altitude. This is clearly a great advantage when flying XC! Just as was the case for Magic Air, there are clouds that can help us find and use convergence lines.

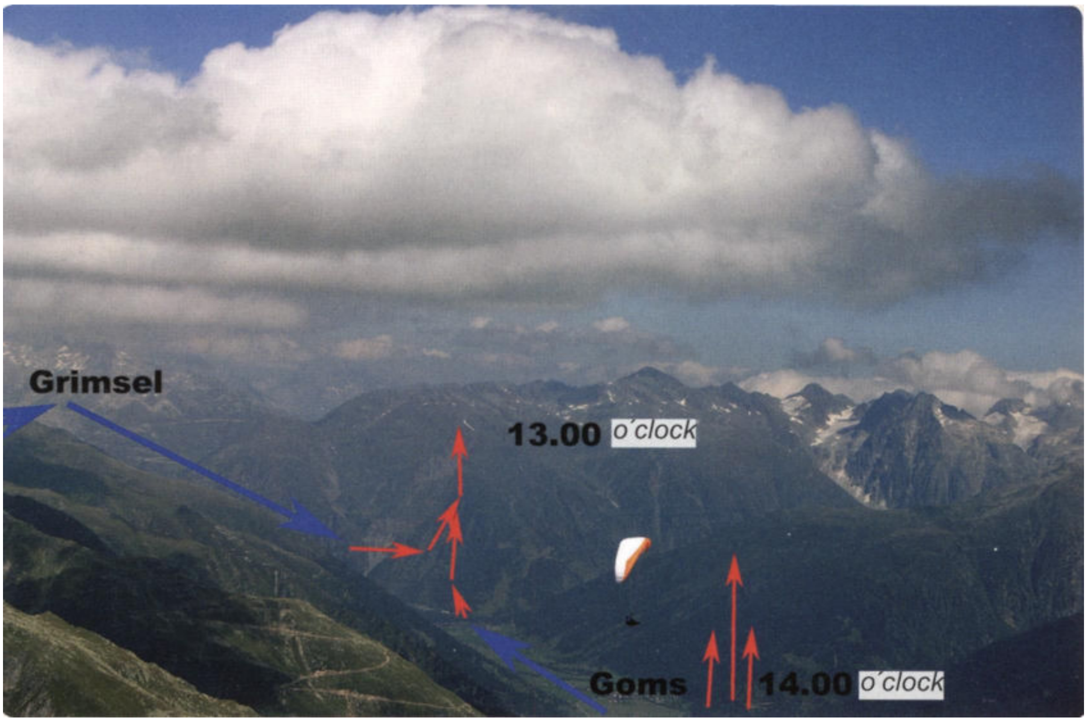
Two valleys meeting in a pass will normally both have air flowing up towards the pass. Once in the pass the air converges and rises as lift - depending on the meteorological wind the convergence line may be offset to either side of the actual pass. If we're wishing to switch valley side we're obviously interested in finding this convergence to minimise our altitude loss, and if no local pilots are available to tell us where it is we have only the clouds to look at. This only works when there are cumulus formations.

Picture 3.33 Typical convergence clouds.

Picture 3.34 Convergence clouds in the Val Sugana on the way to Bassano in Italy. The strong north wind that had accompanied us all the way from home meets the humid air from the Po plains. A great sight, because it means that it is flyable in Bassano in spite of the north wind. The convergence is marked by little cu's.

Illustration 3.34 Convergence in a pass. Both valley breezes are equally strong and the convergence is found directly above the pass. The pilots have found the line and exploiting it to cross the valley.

Picture 3.35 The original photo used for the illustration 3.34. The clouds are forming straight across the Pustertal in Italy and clearly indicate the location of the convergence line.



Picture 3.36 Convergence in the upper Rhone Valley, Valais, Switzerland. The valley breeze coming over the Grimsel Pass is so strong that it pushes the convergence line ever further and further into the main valley. At 2PM it may be 10-20 km down from the Grimsel in the Goms, in the middle of the valley.

Further convergence examples

IThe Gerlos Pass, in the famous Pinzgau Valley in Austria, often sees convergence. Pilots often switch valley sides here and obviously have an easier time when they can locate the convergence line.

2.The Grimsel/Goms convergence in the upper Rhone Valley, Valais, Switzerland. Since the Grimsel wind is stronger than the normal valley breeze coming up the Rhone valley, the convergence line gets pushed progressively further into the main valley as the conditions improve. Around 4PM it is often strong enough to reach down to the main landing in Fiesch, see Picture 3.36.

3. The convergence near the north end of Lake Como, Italy, is also well known. The lake has a distinctive bend here, and both sides of the ridge produce valley breezes. Further explanation next to Picture 3.37.

4. Over the sea we can often observe a cloud wall, formed by the convergence of a meteorological wind blowing offshore and the sea breeze. The wall remains stationary and could probably be used for altitude gains but it is a bit of a gamble...

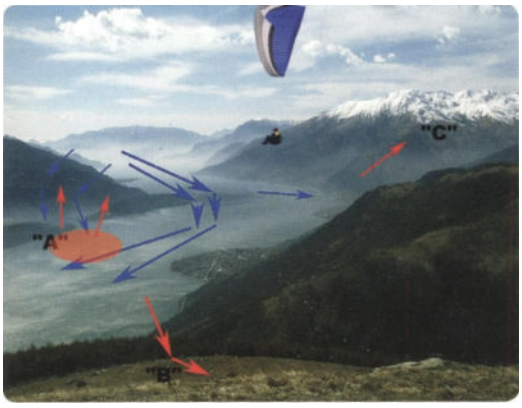
5. When cold airmasses from the sea are blown under warmer air over land they trigger a line of lift. The distance from the shore depends on the wind strength. It is not uncommon to observe conditions where this first line of lift produces cu's - further inland it may be completely blue again.

6. The Inn valley in Austria and the Rhein valley in Switzerland both have valley breezes blowing up them. These winds meet and converge somewhere in the Arlberg region and the resulting convergence is often easy to spot due to the Rhein valley air being moister than its eastern counterpart, causing two different cloud bases within a few km of each other.

Picture 3.38 The sea/land breeze convergence line, here in Andalusia, Spain.

Hint:
Convergences are great to fly when we're high, but nearer the ground we may encounter strong turbulence.

Picture 3.39 Common conditions as they are found on the island of Tenerife, Spain. The sea breeze causes big overshading but the climbing continues, only 2km from the still sunny shore.



Picture 3.37 Convergence on Lake Como, Italy. B and C are typical dynamic soaring ridges, with C being the Monte Mezzo launch. The interesting spot is the A, where the valley breeze follows the bend in the valley. But a small part of it goes over the little promontory and falls back into the valley, meeting the valley breeze again and getting pushed up by it. The area marked in red indicates the convergence, with an area of app. 1 square kilometre and lifting to an altitude of 300m above the lake.

Picture 3.40 When two valley breezes meet, and the one is much more humid than the other, we get staggered cloud bases as seen here, where the group is flying from the higher base towards the lower clouds.

Hint:
Some convergence clouds are caused by the meeting of different winds up high. They look like the ones we have learnt to identify at convergences lower down but bring us no usable lift, as they happen above the levels where we fly. See picture 3.40.

Picture 3.40 High convergence clouds. Of no value for paraglider and hang gliders as they are above our flying altitude.

Lower cloud base in mountain foothills

Compared to areas deeper into mountain ranges, the foothills have a significantly lower cloud base. If a mountain range is oriented perpendicular to the prevailing wind direction the foothills will also get above average precipitation levels due to the air-masses getting blown against and over the mountains by the wind. During high-pressure meteorological conditions, most of the moisture in the air comes from water trapped in the soil- bogs, wetlands and green fields.

Near my home, right on the northern-most edge of the Alps, the cloud base is often 500-1000m lower than only 15-20km further south. Though the valley bottoms are also higher in the central Alps the workable altitude span is still far greater deep in the mountains.

The difference is caused by the greater amount of moisture found in the flatland air, and the higher temperatures in the central Alps (more about this in Chapter 6; Valley breezes).

Hint:
Due to these varying cloud bases it is often possible to fly next to, and not under, clouds. From my home site, the Brauneck in Germany, I often fly west to the Benediktenwand (Benedict Wall) where the cloud base is generally considerably higher. From there I continue to the Jochberg above the two lakes; Kochelsee and Walchensee. The area around the Lake Kochel is very wet and

Picture 3.42 Big jumps in cloud base are common in the Italian Dolomites. North of the Marmolada peaks is the dry high-Alpine Fassa Valley, south thereof the humid air from the Po plains affect the cloud base.

the cloud base there is much lower again - sometimes I approach the next cloud from above rather than from below or from the side! If the sun is shining on me and then down on the cloud beneath me, a Bracken Spectre appears, one of the prettiest sights in free flying.

Picture 3.43 Brocken Spectres appear when we fly between sun and clouds. The thicker the cloud the clearer the spectre becomes.

Picture 3.44 The clouds creeping over the mountain range which borders the Valais (Switzerland) to the south look just like a Fohn wall, but they are only indicating a light southerly wind and a far higher humidity on the south side of the range. The Valais remains perfectly flyable, but going south is not possible. On the north side of the valley, the cloud base may be 1500-2000m higher than what we see in the picture.

Ground level inversions - ground fog

Normally the temperature decreases with altitude. When the temperature decreases fast the conditions are unstable, when the decrease is less significant the conditions are more stable. Sometimes we even see a temperature status quo or slight increase with altitude, and this is called "inversion" because it is the inverse situation of the normal one. Thermals struggle to rise through inversions.

There are various types of inversions, distinct by their altitude over ground. The rapid cooling of the ground during the night causes inversions at ground level; the cold soil cools the overlying air, and the ground-level inversion is formed. The cold air is heavier than the warmer, overlying air so in the morning we encounter a "sea" of cold air in the valleys. In the summer this is best noticed due to smog trapped under it, in the autumn and winter fog forms to cover entire valleys (see picture 5.18, page 150). Such days are great for those going above the inversions, where the skies are clear and the views over the fog-covered valleys magnificent.

It is possible to fly over such "seas of fog" but only when there's either a landing above the fog, or there are holes big enough in it that we may reach the ground safely.

Hint:
Fog layers fluctuate in thickness so to fly safely above them the landing must be well above the upper limit of the fog. Flying through them whilst relying on GPS courses is not advisable - they'll often begin right at ground level, which means that visibility remains almost zero all the way to the ground.

Picture 3.45 Summer in the Inn Valley, Austria. Our feathered friends are already thermalling but we'd better wait one or two hours before launching, as the valley is still covered in the ground inversion. The first humble cu's are forming over the high peaks.

Hint:
There will often be thermals coming off the upper slopes of mountains whose valleys are still deep in ground fog (see picture 3.46). When we wish to fly before the sun has burnt off the fog we must simply launch higher and make sure we do not descend down. Once the sun burns off the fog the thermals will gain strength, as there will then be more land exposed to the sun, heating the overlying air masses.

Picture 3.46 The Krippenstein launch, Hallstattersee in Austria. Flying may be possible; landing in the valley is out of the question. But the pilot is looking forward to her flight!

Picture 3.47 Whenever the fog is not thick, and great gaps are to be seen, the flying becomes particularly scenic. The Bezau/Andelsbuch flying arena, near the Bodensee in Austria. Due to the vicinity of the big lake, this area often has ground inversions and fog formations in the autumn.

Summer inversions in the foothills

The summer time is inversion time along the foothills of mountains all over the world. The inversions appear in connection with stable high-pressure systems setting in, where the air from ground level up to great heights is slowly heated to a very homogenous temperature. There's hardly any mixing happening, and the smog from cars, industry and other pollution sources is trapped under the inversion layer. When this situation sets in along the north side of the Alps, thermal flying all but ceases. The conditions are great for learning to fly, as there is hardly any turbulence and whatever there may be is very weak.

The dirty air is easily observed when looking over the flatlands from the mountains, see picture 3.49.

A good place to escape to, when the foothills are totally covered by inversion, is the central mountain regions, where the inversion problems decrease as we approach the highest peaks.

Picture 3.48 Summer inversion in Bassano del Grappa, Italy. Different rules apply here, as it is often possible to thermal up to the top of the inversion level. This has been called the "Bassano wonderthermals".

Picture 3.49 Summer inversion on the north side of the Alps, little or no thermal development. The picture was taken from the Waidringer Rock Plateau in Austria, looking north into Germany. The smoggy air is clearly visible along the horizon. The small cumulus cloud in the left side of the picture may be caused by the Landshut nuclear power plant.

Hint:
Thermals rising up to meet an inversion become turbulent at inversion level. If we prefer to avoid turbulence it is best to leave the thermal before reaching this level - only 100m lower it is less turbulent. However, on some days a strong thermal may push through the inversion and with some persistence we may go with it through the bouncy part, and enjoy the clear air and spectacular views above the inversion layer.

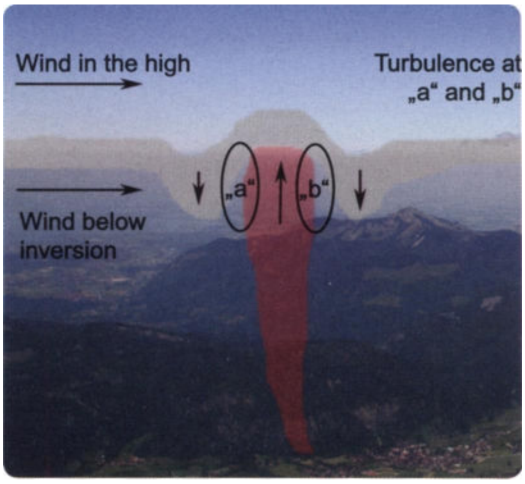


Illustration 3.50 Turbulence in inversion layers. The thermals are stopped at the inversion, and the wind shears caused by different wind strengths and directions above and below cause the turbulence, marked a and b in the illustration. After Volker Schwaniz.

Inversions at mid level - how to climb through them

We often encounter inversions as thin layers at mid altitude on otherwise unstable days. On such days most pilots are forced to fly beneath the inversion whilst a few happy guys make it through and fly around above wearing a big grin on their faces - looking down on other pilots is always a good feeling!

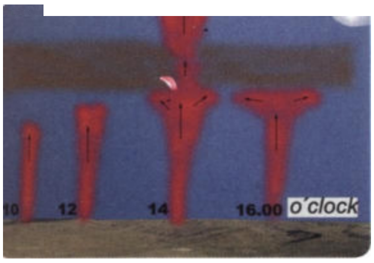


Illustration 3.51 *Around the time where the thermals are strongest we sometimes find a thermal that is stronger than the rest, and thus able to punch through the inversion. If we're lucky there'll be more of these thermals around, and we may continue our flight above the inversion rather than descend down through it again.*

There are two ways of breaking through such inversions and join the smirking crowd:

Illustration 3.52 *A mid-level inversion is stopping the thermals just under peak altitude, above and below it is unstable and flyable. The cloud base is high but the inversion won't let us through. Once through, the upper-level instability would allow us to continue flying high. There are two ways through, either as described in 3.51 or by getting in really close to the mountain sticking up through the inversion. Here, the anabatic air flow seeps through the inversion but the pilot must be prepared to, and able to fly close to the terrain.*

Picture 3.52 and 3.54 *In the Italian Dolomites we often encounter mid-level inversions. To get through we actually soar the anabatic winds flowing up the terrain. Once through, the thermals become "normal" again.*

High-pressure subsidence inversions

During high-pressure conditions a subsidence inversion forms at mid altitude. The mechanism behind it can be compared to a bicycle pump; when we pressurize air it gets warmer. This happens first at mid altitude because the air closer to the ground can escape by flowing off to the sides. Once the mid-level air is heated to a temperature that is higher than the air below it, we have a subsidence inversion. As the high pressure grows older this inversion sinks, progressively decreasing the usable vertical range.

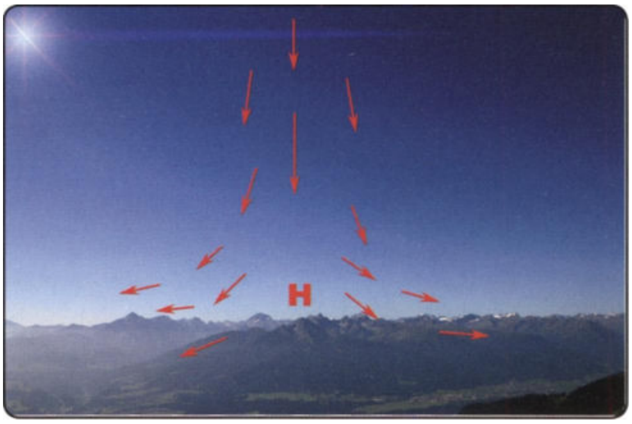


Illustration 3.54 During high-pressure conditions air sinks down and gets compressed, creating a subsidence inversion. It forms at mid- to high altitude first because the air nearer to the ground can escape to the sides. The sinking air moves at several centimetres per second.

The typical progression of this high-pressure subsidence inversion is depicted in Illustration 3.55. Once the high pressure is replaced by cold air flowing into the higher areas the airmass becomes unstable again, and the last day of a high-pressure period may again be XC suitable.

We all know that during high-pressure spells the cumulus clouds dissipate after their brief lifespan. If this wasn't the case, the sky would soon be covered and no more sunshine would reach the ground. But why do the cu's dissipate? The sinking air from above pushes the cloud down, thereby compressing and heating it. Warm air can hold more moisture than cold, so the cloud disappears! Mixing with the surrounding air due to turbulence and wind speeds up this process.

If you're into curio you might want to know that the descent rate of the subsidence inversion is in the order of magnitude of around 1/100 of thermal climb rates.

Explanation Illustration 3.55 (following page)

Day 1:
Right after the trough/cold front passage the air is humid and the cloud base is low. A high-pressure ridge is approaching. Early on the inversion is still very high, and the cu's can grow tall - sometimes we even get showers and CB formation. But the situation is rapidly stabilising and the cloud base is getting progressively higher - the clouds grow flatter. Such days are great for XC flying over the flatlands, but in the mountains the clouds tend to congest, especially if there's wind, and the rain persists for another day.

Day 2:
From now on the flying conditions in the mountains are very good. Cloud base continues to rise, the air is drying and the subsidence inversion is sinking down, reducing the risk of overdevelopment. Expected climb rates as in Illustration 1.35.

Day 3:
Early in the day we may still see minor cu development, later the inversion sinks below the dew point and the day goes "blue". Still good flying and XC conditions with climb rates as in Illustration 1.38

Day 4:
By now the inversion has sunk so low that flying is hardly possible. Climb rates as in Illustration 1.40

Day 5:
By now the subsidence inversion is almost at ground level. If no major perturbation occurs a new inversion may begin to form up high. If the sun is able to burn off the ground inversion the day may become very good for flying, with a very high cloud base due to the low moisture content in the air.

Note that all this is an idealised model, and that nature has many variations up her sleeve. The entire process may take as little as two or as much as 8 days to conclude. However, a basic understanding of the cycle makes it easier to predict and understand flying conditions.

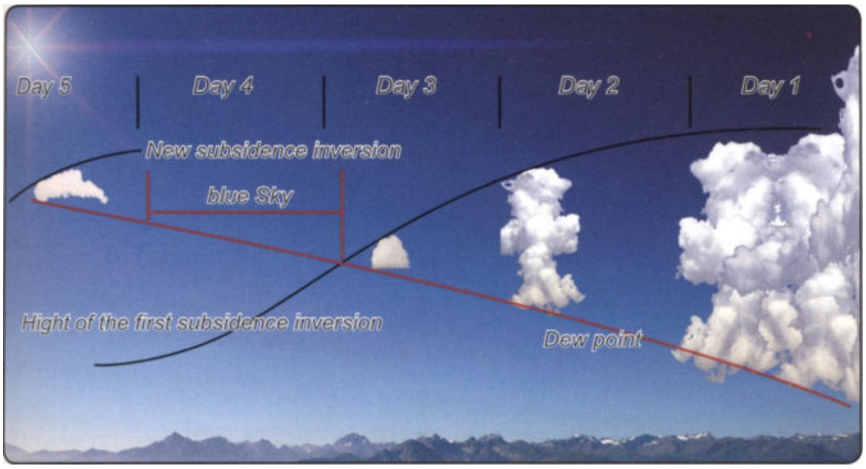
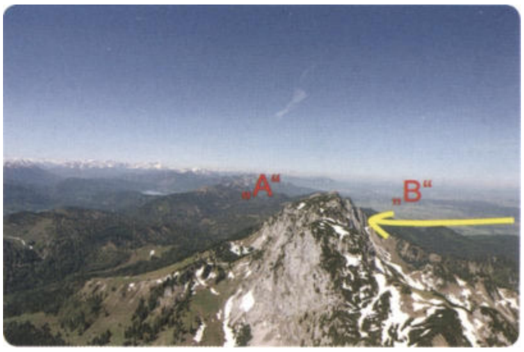


Illustration 3.55 High-pressure inversion development seen over the course of a few days. The red line is the dew point where the rising air reaches 100% relative humidity and clouds begin to form. The vertical growth of the clouds is decided by the inversion altitude (black line). The further these two lines are apart, the taller the clouds may grow. Once the inversion sinks below the dew point, the skies become blue.

Experience:
One of my longest flights ever was done in conditions like the ones described under "day 2", with the clouds growing worryingly tall in the beginning of the day. In fact many pilots opted to land for fear of overdevelopment, but I kept observing the clouds and detected a tendency towards dissipation. I flew on, and managed a flight long enough to win me the German OLC title in 2004.



Picture 3.57 Once the valley breeze (yellow arrow) is fully on, we limit our thermal search to the north (B) side of the ridges. But early in the day, before the valley winds grow strong, we use the south (A) side. The picture shows the Benediktenwand above Lenggries, Germany. This is my first station when flying west from my home site.

Flying in the lee of mountain chains

If the macro-meteorological wind is not strong, it is perfectly possible to fly on the lee side of a mountain chain. In the Alps we often fly the south side in weak northerlies, or the north side in weak southerlies. As soon as the valley breezes set in, it is important to know which side of a mountain to approach when crossing valleys. In the northern Alps the valley wind systems, once active, often reach high enough to overflow the ridges and cause leeside conditions on what from a macro-meteorological viewpoint should be the windward side! Thermals are first offset towards the south, and then when they push through the wind shear they are offset back towards the north. The question we must ask ourselves when flying such conditions is "will the valley breeze be strong enough to push over the top of the next ridge?". If we answer affirmatively we must approach the north side (where the valley wind comes from) to avoid finding ourselves in the lee. If the answer is negative we approach the south side.

Hint:
It is common for south-facing launches in the northern Alps to have a tailwind setting

up around noon on thermally active days. In many places this is a good thing, as there are also north-facing launches available. I have noticed that as soon as the first wafts of tailwind sets in on the southern launch it is no longer possible to climb out from there, even if launching is still possible in the lulls. But the valley wind lee creates a smooth but strong sinking bubble where unlucky pilots descend with 3-5m/s until they land.
This means that if we didn't get off before noon, it is best to wait another hour until the thermals have begun rising up the north face, and launch here. These thermals do not originate on the north slopes; they are warm air from the flatlands below being pushed up the north face by the wind.

Thermal lunch break in the foothills

The thermal activity begins in the late morning, and it is not uncommon to see a number of early pilots circling in the still weak lift. But suddenly the thermals die and the pilots slowly descend out - we call it the "thermal lunch break".

The mechanism is as follows: In the mountains, and the mountain foothills, the thermals begin working earlier than in the surrounding flatlands. But as the thermals grow stronger the mountains begin to draw in colder air from the surrounding flatlands, where it suppresses the thermal development for a while, until it has been heated sufficiently to begin rising as thermals. This process takes around 30-45 minutes and generally no usable lift is found during this break.

Hint:
On weaker days the thermal lunch break may last even longer, whereas on strong, unstable days it may be all but indiscernible. In the central Alps, far from any flatland influence, I have never been able to discern the existence of a thermal lunch break with any certainty.

Thermal lunch break near the sea

The oceanside lunch break is caused by very similar mechanisms to the foothill ones. Here, the cold air being drawn in by the beginning sea breeze effectively stops thermal development, which is also the reason why the best thermalling close to the sea is generally early in the day. Once the sea breeze sets in the thermals become weak or nonexistent and at the very least the cloud base lowers due to the humid sea air.

One advantage that coastal sites have is appearent in the winter; due to the often warmer sea the air doesn't cool so drastically during the night and the ground inversion in the morning is thus less dramatic. Combined with a low sun heating the slopes, this is often sufficient for usable thermals to form. The popular winter site at Monaco is a good example of this.

A second advantage that coastal sites have is on very unstable days, where storm cells form inland and drown any hope of flying; but near the coast the weak thermals don't have the energy needed for storm development and the flying may continue long after the inland sites have been shut down.

Picture 3.58 The beginning of the sea breeze effect is the cause of the oceanside lunch break. In the mountains the onset of the valley wind systems have a similar effect. In this picture the pilots fall out collectively in spite of recently good thermals.

Picture 3.59 The "lunch break effect" has advantages too. In Monaco it is often flyable long after storm development has effectively put a halt to any flying only a few kilometres inland.
The same is the case in the picture in Wilderness, South Africa. No clouds above the sea but overdevelopment 20 kilometres away. Seaside soaring is possible.

Thermal lunch break in hill country and flatlands

Even in flatlands or low hills we may experience the thermal lunch break phenomenon, albeit caused by entirely different mechanisms. The assignable cause this time is the wind, and the wind may also help the hill-country pilot to stay in the air during a thermal pause, by allowing the soaring of small ridges.

On days with any wind the ridges or low crests are often the thermal triggers in low country. The wind pushes the warm air along the ground, and when it reaches a terrain protrusion it is triggered to form thermal columns. This mechanism is quite reliable in hilly to nearly flat terrain, but when the wind abates it gets more complicated.

But why would the wind suddenly abate?

In a high-pressure region the wind blows towards the low pressure. Near the ground the high inversion funnels this wind, but as the day grows warmer the inversion lifts; the wind has more vertical space to move in, the funnel (or „venturi") effect is reduced, and the wind at ground level abates. Note that this only happens when the macro-meteorological wind is not particularly strong.

down.

Picture 3.60 In the flatlands and in low mountains a brief thermal break will generally see us on the ground. To avoid this XC beginners should only launch after the thermal lunch break, often around 1 to 2 o'clock PM. As always, beginners should avoid flying during the strongest time of the day.

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Dustdevils are common in desert regions. This picture shows the towing site in De Aar, South Africa.

Dust devils

Pilots fear them and spectators are fascinated by them. Dust devils occur when the airmass is over-adiabatic, i.e. when the air near the ground has been heated to temperatures where it should have risen as thermals long ago, but there hasn't been a triggering impulse yet. When the triggering impulse arrives, for example in the shape of a gust creeping over the crest from the windward side, the thermal rises with a vengeance, rotating and forming a dust devil as it goes.

When the air is particularly unstable mountain regions often have dust devils forming off sunny lee-sides. On such days the pilots either launch into the wind on the windward side, or into the thermal breeze on the leeward side.

The launch at Babadag in Oludeniz in Turkey is renowned for its dust devils. It is an example of the situation described above, where the south facing launch often has wind from the north - a virtual dust devil recipe.

Experience:
Once I saw a paraglider complete with harness taking off in a dust devil and looking almost normal until about 20m off the ground - shortly thereafter it was nothing but a bundle of cloth and lines. And at the Babadag launch, mentioned above, one pilot getting ready for launch got picked up by a dustie and did a full loop from standing - luckily his injuries were only minor.

When launching from dust devil-prone launches it is highly recommended to wait until one has gone through, thus releasing the overheated air. Right after a dust devil has gone through, the probability of another one forming, is much reduced. Flying into dust devils at low altitude is very dangerous.

I was towing in Australia when a sudden dustie came my way. As I was only 150m above ground I decided to release and escape. I was back on the ground in no time, battling my flapping wing in a bundle due to the +40km/h winds. Since that little incident my flying suit has some very decorative holes in it. The locals later told me that they often fly into dusties as long as they are more than 300m above ground - lower than that and even the most hardcore of them steer well clear. I wouldn't recommend flying into dusties at any altitude, but as this story shows some pilots do.

Conversion table see page 21.

Picture 3.61 Kobala launch, Slovenia. The wind was light easterly and the launch faces into the strong afternoon sun. This is dustie heaven, as the photo shows. Compare with the picture 1.46, page 50.

Hint:
Dust devils are also thermals. When encountered at an altitude, good pilots may choose to fly into them to climb. When doing so it is always best to enter against the turn direction as this will have the wing pitch back - less dangerous than flying with the rotation direction and have the wing diving forward upon entry. I always advice against dust devil flying due to the strong turbulence often associated with it - experts only!

Smoke and dust as thermal markers

If you observe two smoke trails drifting towards each other chances are that there'll be a thermal rising from where they meet. Thermals suck in air from all around, and the effect is easiest to observe on windless days. If the two smoke or dust trails are drifting away from each other there's no thermal.

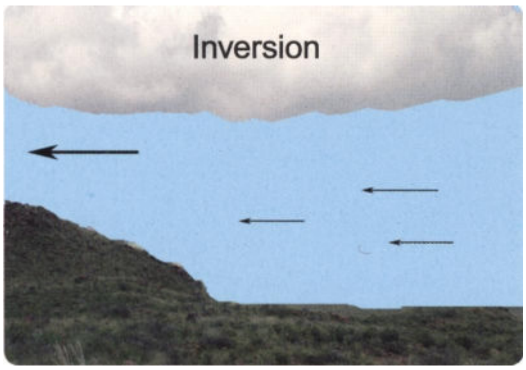
Picture 3.62 Two smoke trails drifting towards each other. Where they meet (red circle) there's a good chance that a thermal is releasing. The hang glider pilot has noticed it and is aiming right for the thermal. Low down the lateral drift is stronger. This means that two pilots thermalling at different altitudes in the same thermal column will experience differentiated drift, with the lower pilot drifting more!

Illustration 3.63 Inversions often magnify venturi effects. As seen in the drawing the hill and the low inversion combine to make the wind stronger at hilltop level.

Using smoke to learn about inversion levels

Smoke stacks are also handy for judging the stability/instability of the lower levels - and if the smoke rises high we can even use it to learn about air movement and stability at higher levels. If the smoke is rising vertically we know that there's no wind, and when the smoke rises to a very well defined level only to be spread out along it we know that there's a strong inversion at this altitude. As long as this phenomenon is visible along the valley floor we can expect very calm conditions.

Picture 3.64 Rising smoke meets the inversion and spreads out horizontally. From this picture we can't say anything meaningful about the possible turbulence at higher levels, but beneath the inversion there's not going to be any turbulence at all.



Systematic thermal hunting

In the long run thermal flying should cease to be coincidental. To achieve this the pilot must learn to search for lift in a systematic manner. Here are some tips, in order of importance:

- The single most important factor is the wind. Where is it coming from? If the wind is coming from the north the pilot should concentrate on searching north, northeast or northwest slopes.

- Second most important is the sun. The best thermals originate from areas oriented perpendicular to the sunshine direction, especially if they have already been exposed for a long time.

- Where are the trigger points? Are there any obvious triggers given by the terrain? Remember that the most important trigger is the mountaintop! If this isn't usable (low cloud or shade all around) then look for snow lines, streams or rivers, motorways, and don't forget shadow edges edges! Whenever a cloud shadow is moving over the terrain with the wind, the upwind shadow edge is the best potential trigger point.

- And all the rest of the questions: Which kinds of soil do we have available? Forest clearings are better than deciduous forest, rockslides are better than the surrounding coniferous forest (see picture below), mountain pastures, especially those surrounded by woods, are always good. The good pilot always attempts to take the wind drift into consideration when basing the search on ground sources.

- In the flats it is less straightforward. The thermal sources are less obvious, but some good examples are grain fields, sandy soils, earthen dikes, highways and junctions, riverbanks etc.

Picture 3.65 This last step before the high plateau is likely to be very good for releasing thermals. The most promising spot is the rock slide right behind the pilot.

Thermal hunting in hill country and low mountains

By Volker Schwaniz

The Albedo value of the ground is very important for the heating of the air - but it doesn't reliably tell us where the thermal actually can be found. In real-life flying we will often experience situations where a mass of warm air is pushed along by the wind until it meets a trigger point, where it releases as a thermal. This is the reason why flight routes going over large expanses of homogenous terrain are less promising than routes following valley sides, where there are often tree lines, power lines etc. to trigger the thermals.

This is particularly true when the wind increases in strength - then trigger points overtake ground sources as our number one thermal search locations.

Hint:
On no-wind days we use our understanding of Albedo values to locate the thermals. There's no wind to push the overheated air away and against a thermal trigger, so we have to depend on the thermal releasing from its actual source.

Picture 3.67 Same day/location as picture 3.66 but a different angle of view. Again we notice the more promising looking cloud picture over the hill country compared to the flats.

Hint:
When the wind is light we look downwind from the best-heating areas (the ones we were using above). If the wind is really light the thermals may come from both the actual sources and from just downwind of the sources.

Hint:
As the wind gets stronger our focus shifts towards trigger points downwind of the most easily heated areas.

Picture 3.66 The cloud distribution is a good thermal and day quality indicator. This reference day had the following conditions:
Weak winds, April day with polar air influence and low base. The soil was very dry. Notice that in spite of the ideal soil for thermal development in the flatlands, the thermal quality is still far better above the hills.

*

Searching for flatland thermals down low

1. Where's the wind coming from? Flatland flying means less leeside worries, but even a small hill may cause a serious rotor.

2. Is there anywhere where the landscape is oriented better against the sun?

3. Where is the best soil for heating?

4. Where will the thermal be triggered?

This brief checklist can be summarised into an even briefer sentence: First look for easily heated soil, then try to visualise where the thermal will release!

Picture 3.68 A dark field is a good thermal factory.

Searching for mountain thermals down low

The checklist is the same as in the flats, but the order of the points is different;

Point one is even more important in the mountains, as leeside flying should be avoided. But since we generally find mountain thermals where they are released rather than where they are produced, we must go straight from point 1 to point 4. If this happens to be downwind of a location of warm air production then we made it. Point three can generally not be taken into account once we find ourselves low in a valley. Remember: Our main concern in the mountains is to stay out of the lee.

Picture 3.69 When thermal hunting over relatively even ground there's less reason to worry about lee. But if we're low enough to discern hills (like the one in front of this pilot) we should generally aim for them, as they are often good thermal triggers. It is hard to make out hills from higher altitudes.

Hint:
To summarise the mountain search pattern rules: Stay out of the lee and aim for thermal trigger points.

If we have a choice between deciduous and coniferous forest we choose the second. If around noon we have a choice between a steep mountainside and a rounded knoll we choose the second. Note that neither of these choices is common in real-life flying!

Searching for thermals from high altitudes

Once we are high life is much easier; we got many options and we have plenty of time to search. Furthermore flying high allows us to use the clouds as thermal indicators. We fly towards cu's still building and avoid decaying ones, and we remember to keep observing our surroundings whilst thermalling, especially in our intended flying direction. By doing so we may notice new wisps of cloud forming and observe them long enough to know if they are worth aiming for. We explore clouds in detail in the next chapter.

Picture 3.70 Cassonsgrat, Flims, Switzerland.

Picture 3.71 Never fly in the lee when the wind is strong. First work out where the wind is coming from, then aim for the most promising looking trigger point. The picture shows the Churfirsten flight arena in Switzerland.

Picture 3.72 Once we have made it to cloud base we use the clouds to direct us from one thermal to the next one. Aim for cu's that are still forming and avoid decaying ones. All pilots should practise visualising where the thermal is coming from - this helps us to improve our thermal hunting when down at low altitude. At mid level we must learn to aim right between the source and the cloud to find the thermal. Pinzgau Valley, Austria.

Chapter 4: Clouds

Clouds, and especially cumulus clouds, used to be simply annoying when I wanted to get some sun on my face. Nowadays I look at them from a different point of view, in fact I am practically ALWAYS aware of the clouds above me; and when they look good immediately I start dreaming about flying. My studies of the skies are more than a pleasant pastime though - cloud observing helps me to become a better pilot.

Forming, dissipating

Our beloved cumulus clouds are made of tiny water droplets. To understand them we need to look briefly at how clouds form.

The sun heats the ground, which in turn heats the overlying air. The air expands and becomes lighter, and eventually rises as a thermal. While rising the air cools down adiabatically, which means about 1 degree per 100m altitude. The cooling is primarily caused by the expansion of the air and only on a very small scale by mixing with the surrounding, colder air.

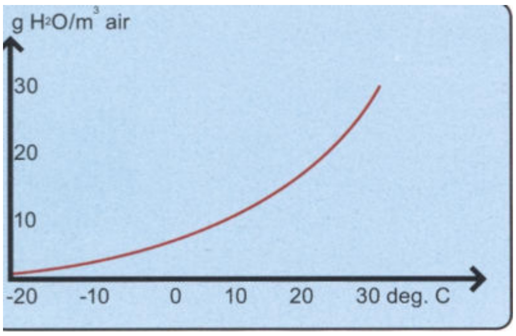


Illustration 4.1 Maximum water absorption per cubic metre of air, as function of air temperature. The warmer the air becomes the more water it can hold. At 10 degrees centigrade air may hold about 10gramm of water per cubic metre.
We saw in the previous chapter that air in high-pressure systems is perpetually sinking. This means that the air containing the clouds is also sinking, and getting warmed up, which eventually leads to the dissipation of the cloud.

To explain adiabatic cooling/heating consider the following example: When we use a bicycle pump we are familiar with the fact that the compression of the air causes it to heat up. The opposite is also the case; when air expands it cools down. This is what is known as "adiabatic temperature change", which simply means that it takes place with no external influence and no energy is added or deducted, and no mixing with surrounding air masses occurs.

The rising thermal contains the moisture present at ground level, but as it cools down the relative humidity increases as the temperature drops. If it continues rising up to the dew point the humidity condensates - the cloud starts forming. The cloud continues to grow as long as there's still new warm air, and thus humidity, being added from below.

In a high-pressure system (where the air pressure is high at ground level) the air is always sinking slowly. The sinking motion happens at a rate of centimetres/hour, whereas thermal climb rates are measured in metres/second or feet/minute. But the slow sinking of the air is enough to push the clouds downwards as soon as the thermal ceases, which in turn increases the pressure of the general air mass. And the increased pressure causes the temperature to rise (see above) so that the relative humidity decreases - the cloud dissipates. Adding to this effect is the mixing that happens with the surrounding, drier air. Once the cloud has disappeared completely the sun may heat the ground again, and the process repeats itself.

Cloud coverage

When we talk about cloud coverage we use the term oktas, or increments of 1/8. A blue sky with no clouds has 0/8 cloud coverage, whereas a completely covered sky is referred to as 8/8. In the weather forecast it may be given as follows:

Cloud coverage in oktas		
Oktas	Description	META Rabbreviation
0/8	Sky Clear/ Clear	SKC
1-2/8	Few	FEW
3-4/8	Scattered	SCT
5-7/8	Broken	BKN
8/8	Overcast	OVC

Table 4.2 Cloud coverage in oktas.

Illustration 4.4 Climb rates under clouds are generally best under the thickest part of the cloud. When approaching a cloud, fly straight for this area. From beneath it can be located by its dark grey colour.

Picture 4.5 Clouds streets will also have thicker, darker sections indicating where the best climbs are found. This hang glider has noticed the most promising looking section and aims straight for it.

Picture 4.3 Scattered clouds (3/8) in the Pustertal, Austria.

Locating the area of best climb under a cloud

Once we're high we may use the clouds to locate the best climbs. Normally these are found under the thickest part of the cloud, which is where the cloud looks darkest when observed from below.

When approaching a cloud is pays to do so in a way that brings us directly to the thickest/darkest part of the cloud. To do this we must also consider the wind direction at cloud level, as the best climbs are often found on the upwind side.

Hint:
Flatland thermals often set up in rows following the wind direction. For the flatland pilot this has the benefit that when exiting a thermal the most likely location of the next one is directly downwind - just as the cloud streets indicate, see picture 4.6 and 4.39. Notice that this is also the case on blue days! If we must fly cross wind it follows that our best strategy is to fly perpendicular to the wind direction until we have connected with the next cloud street (or thermal line, on blue days), then follow that for a bit downwind until we make the next jump perpendicular to the wind. Flying at any other angle between thermal lines increases the distance between them and therewith our risk of landing whilst crossing the gap.