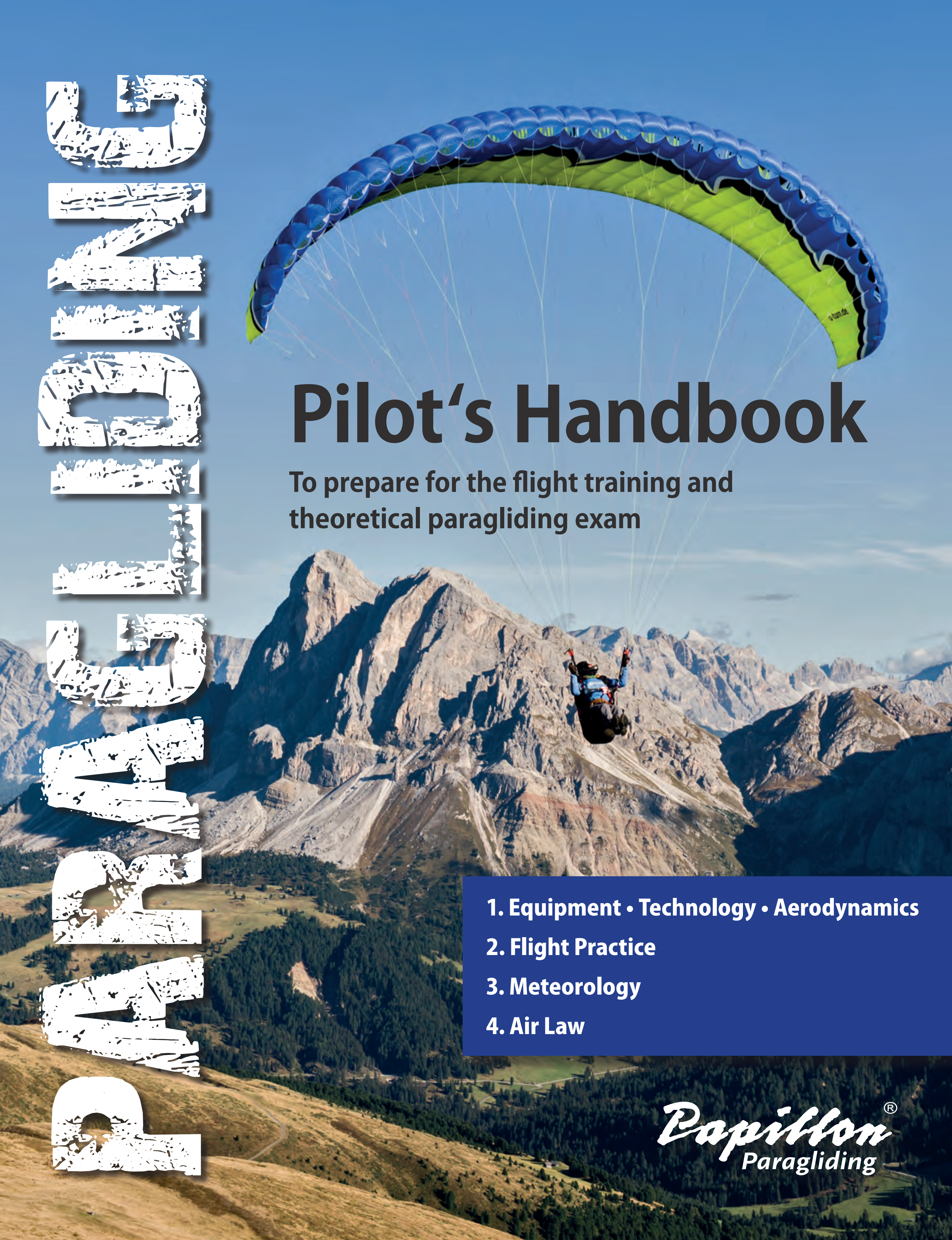


PARAGLIDING

Pilot‘s Handbook

To prepare for the flight training and theoretical paragliding exam

1. Equipment • Technology • Aerodynamics
2. Flight Practice
3. Meteorology
4. Air Law

Papillon® Paragliding







ICARO

"I walked slowly against the wind and suddenly felt the lifting force. The next moment I lost the ground under my feet and glided gently downhill through the air. The feeling when you fly is highly gratifying and quite indescribable!

This is how Irvin Wood, the first flight student of human history, described his first gliding flight, which he performed in 1896 under the guidance of Otto Lilienthal. About 90 years later, paragliding developed into a sport that attracts thousands of people around the world.

Satellites orbit the earth, people fly to the moon and build supersonic passenger aircrafts - but until recently nobody thought about the possibility to fly with a wing without a rigid structure. This revolutionary development is closer to the ancient human dream of flying than any other air sport.

Learn how to fly safely and happily

Paragliding does not only look easy and safe – it actually is. Thanks to the Papillon standards for safe paragliding, almost anyone can experience the great adventure of flying today.

However, paragliding can quickly become an extreme sport; for example when out of ignorance or carelessness a too sophisticated glider is flown in meteorologically challenging conditions.

This pilot handbook teaches you the theoretical and practical basics which are needed for safe paragliding. It does not replace the theory lessons, but will support you in preparing for the theory test towards your licence.

For your paragliding training we wish you great fun, lots of success and many beautiful flights!

See you UP in the sky!

Your Papillon Team

Author of the chapter: Equipment, Technology, Aerodynamics

Paul Seren, born in 1959, is Dipl. Ing. for aerospace engineering and has worked for 12 years in aircraft maintenance with the Air Force.

Paul is a hang glider pilot since 1979 and a paraglider pilot since 2003. He has a flying wife and four flying sons. „I am so enthusiastic about flying that I have infected my whole family with this virus over the years."

1 Equipment, Technology, Aerodynamics

What a special experience to fly with a paraglider and enjoy the scenery! It is particularly surprising that this is possible with a few metres of fabric, some suspension lines and us as the carried load.

This first major chapter will help you to develop an understanding of the interrelationships of aerodynamics and the design of a paraglider.

1.1 Principles of Flight

For a long time people have been trying to understand the secret of flying. Although there have been many examples in nature, the imitation attempts were consistently marked by a lack of success.

A major reason for the failure was an insufficient consideration of our role models:

They assumed that the flapping of wings and the feathers were mainly responsible for the movement through the air.

The focus of the constructions therefore was on apparatuses that were able to flap like wings - either by direct muscle strength with feathers draped on the arms (Icarus and Daedalus from the Greek mythology, Figure 1) or by mechanical devices (Leonardo da Vinci, 1452-1519, Figure 2).

Figure 1: Icarus and Daedalus

Figure 2: Wing sketch by Leonardo da Vinci

Unfortunately, the muscular power of humans is not strong enough. While the body weight of humans consists of approximately 20-25% arm and leg muscles, half of a bird's body weight is muscle mass.

Humans are too weak, but smart! Evolution has spawned flying mammals. Since the invention of flying machines about 120 years ago humans belong to this group.

One of the first explorers and pioneers of flight mechanics was Otto Lilienthal. He had mentally separated the topics „thrust" and „lift" in his observations. His studies were derived from the observations of circling storks, which he has analyzed intensively.

The main finding, which was confirmed in his numerous experiments, was the presence of a so-called aerofoil camber (Figure 3). This curvature causes not only a significant lift component, but also provides a propulsive force, which allows gliding.

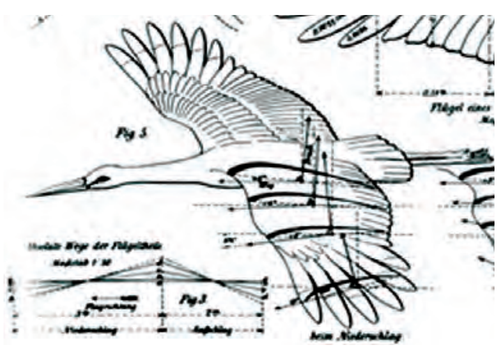


Figure 3: Lilienthal's observations

Owing to his fundamental investigations he could develop the first truly airworthy, manned aircrafts and successfully test them in the air (Figure 4). His investigations also showed that different curvature shapes have different lift and drag characteristics. He summarized these observations in a so-called L/D polar curve.

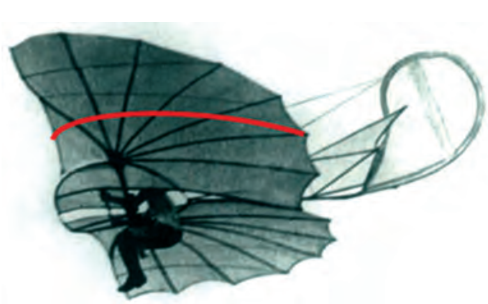


Figure 4: Otto Lilienthal gliding

A fundamental property of almost all profiles is that 2/3 of the lift are generated by the negative pressure on the top of the wing, and only 1/3 of the lift is generated by the excess pressure under the wing (Figure 5).

On a paraglider in trim speed the lift is strongest in the front third of the profile, in the middle part of the wing.

The great thing about paragliders is that the wing is not made of solid materials. An easier way was found to build a supporting surface of fabric, around which the air can flow.

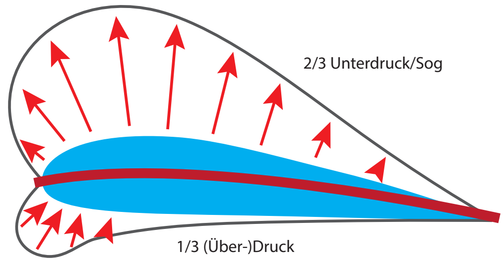


Figure 5: Pressure distribution on an airfoil

1.2 Construction of a Paraglider

1.2.1 The Canopy

Compared to other kinds of manned aircraft, the wing (also called canopy) of a paraglider has a very special feature:

A portion of the air flowing around the wing is used to blow it up in order to establish the necessary internal pressure to keep the canopy inflated. To allow this, there are cell openings at the leading edge of the wing while the trailing edge is closed.

The upper and the lower surface are connected through cell walls. The leading edge of modern paragliders is on the lower half of the nose curvature so that the air can flow easily into the canopy.

These cell walls, also called cell ribs, are largely responsible for the curved profile shape described above.

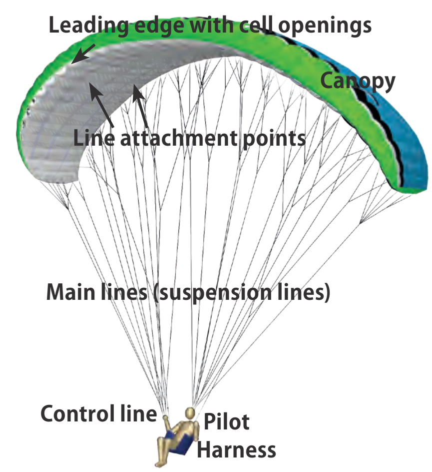


Figure 6: The main elements of a paraglider

In addition, these ribs are perforated: Crossports enable the internal airflow and the maintaining of pressure throughout the entire canopy. In an air-filled paraglider, the individual cells are clearly visible.

To keep the pressure inside the wing, the material used for the canopy is usually a very dense, lightweight coated fabric made of polyamide (rip-stop nylon), which has a very low air permeability and a particularly high tensile strength.

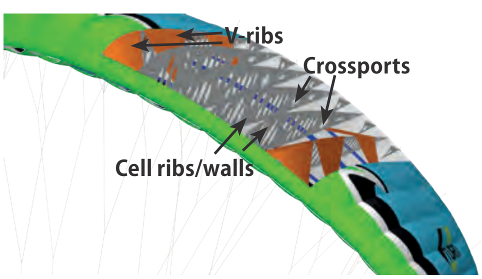


Figure 7: Interior view of a paraglider

Another design element are so-called V-ribs or diagonal ribs, which are diagonally sewn to normal ribs. They support the internal force distribution to multiple chambers and thereby reduce the number of line attachment points needed. This reduces the total line consumption and thereby the drag without adversely affecting the profile (Figure 7).

Transverse bands, which are sewn in the span direction, increase the canopy stability and reduce the so-called self-oscillation of the glider.

The leading edge is reinforced for two reasons: On the one hand the filling of the canopy during the launch is supported; on the other hand it is important to ensure high profile accuracy where the air impacts the wing.

This high profile accuracy needs to be maintained even at high speeds, when the back pressure acting on the nose increases with speed.

At the same time, the wing should remain flexible and not too rigid at the leading edge. Therefore, reinforcements, for example of Mylarfoil and/or plastic sticks, are sewn into the canopy.

Stabilizers at the wingtips optimize the directional stability of the wing.

To ensure permanently safe flights, a careful handling of the equipment is important. This lessens the risk of accidents and increases the fun of flying.


Figure 8: During the launch air enters through cell openings at the leading edge of the canopy and inflates it • Photo: Felix Wölk

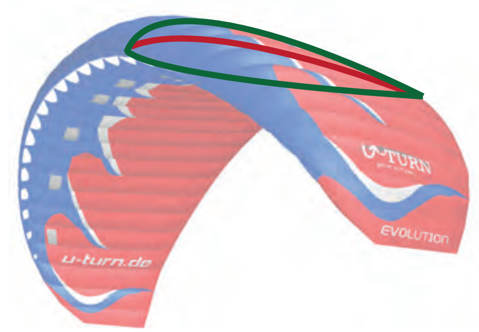


Figure 9: Profile of a paraglider

Figure 10: All lines untangled? • Photo: Felix Wölk

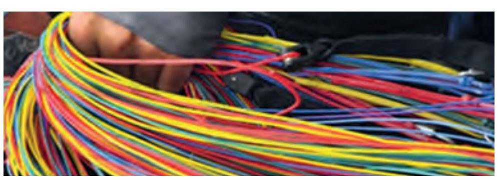


Figure 11: Lines – Each line level has a different colour to help in untangling the lines and to faster recognise each level.

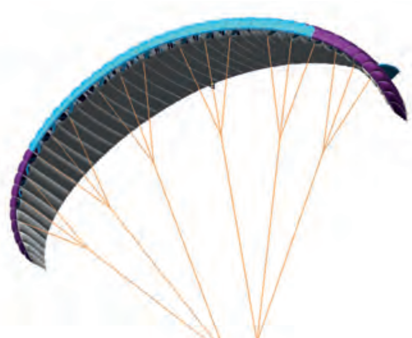


Figure 12: Exemplary individual line level (A-level) . Illustration: Advance

Figure 13: Aramid (top) and Dyneema (bottom) lines

Sunlight and mechanical stress (for example, dragging the wing across the ground while ground handling) can damage the coating of the fabric.

If the paraglider became wet after landing on a wet meadow, it should be dried in a shady place before packing.

Contact with chemicals (especially battery acid) should be avoided. The canopy and the lines may be so severely damaged that the equipment must be checked by the manufacturer before the next flight.

It is important to clean a dirty paraglider with clean water only.

Small rips (up to 5 cm) in the canopy can be repaired by the pilot with adhesive repair patches (on both sides). Larger repairs are carried out by specialized companies. During the periodic inspection (2-yearly check) of the glider, the air permeability of the fabric is checked.

To support the longevity of a paraglider, hard ground (tar, concrete, gravel) should be avoided during packing.

Reinforcement sticks at the leading edge should not be folded and air should not be pressed through the fabric. Over time, there may be accumulations of dirt, sand or snow in the canopy. Many paragliders have an opening at the stabilizer of the wing to remove these materials.

Aged paragliders should be replaced. Old canopies can have a detrimental effect on the launching behaviour and an increased stall tendency. The stretch resistance and tensile strength are also reduced. Aged equipment can often be identified by a faded colour.

Since the canopy cannot fly on its own, it must be connected to the pilot and his harness.

This is done via the so-called ...

1.2.2 Suspension Lines

In 1990 the total length of all lines in a paraglider was about 600 metres; today the average is only 300 metres. Yet, these are perfectly suited to carry our weight. Each line can carry a load of up to 100 kg (main lines even up to 200 kg).

The line layout follows a simple way of thinking. In the horizontal direction there are several rows of lines, which are attached to the line attachment points of the wing. These lines are not sewn to the canopy; they are „looped". Therefore they can be replaced easily by specialist companies if necessary.

Paragliders have three or four sets of lines, which are counted backwards from the leading edge and called A-, B-, C- and (if present) D-levels. Some older models still have D-lines. Modern paragliders are usually equipped with only three levels of lines, which reduces the drag and increases the glide ratio.

Even paragliders for beginners have a considerable performance these days.

The weight forces (pilot, harness) are fanned up to the canopy. The fewer but thicker main lines are connected to the risers via quick links. They cascade into smaller diameter lines near the canopy, where they are looped to the wing.

In flight, about 2/3 of the load is on the lines of the A- and B-level, while only about 1/3 of the load is distributed to the C- and D-lines.

The total strength of all main lines of the A- and B-levels must be at least eight times the maximum allowable takeoff weight and may not be less than 800 kg.

Main lines consist of sheathed Aramid („Kevlar™“). This fibre is particularly tough and resistant to heat and stretch. However, it also has a lower UV resistance and higher sensitivity to bending.

Therefore, a good protection is necessary. This can be achieved through a coating with the additional positive side effect that it also protects the core material against abrasion.

Lines in the upper cascaded section can have a smaller diameter because the weight force is distributed to a higher number of lines.

The material that is often used for the lines in the upper cascaded section is Dyneema™, a white synthetic fibre based on polyethylene. This fibre is kink-, stretch- and UV-resistant and has a particularly high tensile strength. In relation to its mass, Dyneema has a fifteen times higher tensile strength than steel. However, it is not as heat resistant as Aramid (Figure 13).

It is important that the lines have a certain length, as defined by the manufacturer (depending on the paraglider they may only differ between 0.5 and 1.5 cm).

The control lines should be set in a way that the entire speed range of the glider can be flown without any problems. This setting must not be changed, because the predetermined brake line play is very important for the safe behaviour of the paraglider.

If lines are shortened (for example by shrinkage of Dyneema), the free travel can be reduced so much that problems may arise when launching or accelerating the paraglider. Moreover, the extreme flight behaviour would be aggravated drastically.

When the core or coating of a line is damaged, the whole line needs to be replaced by an expert before the next flight. The lines have to be checked during the regular inspection, but also after a landing in a tree or in water or when an unusual flight behaviour is noticed. The person doing the check will measure and record the individual line lengths and control their tensile strength.

1.2.3 The Risers

The different layers of lines and the control (or brake) lines are connected through quick links (Figure 16, 1) with the risers, which comprise all lines in a well-ordered manner.

The brake handle (2) is knotted at a defined distance to the lower end of the control line, which runs through an eyelet (control guide) attached to the rearmost riser (3).

The lower end of the brake line is also called the main brake line. Further up it separates into several thinner lines.

The foremost riser (A) is divided: The outer A-line has its own riser portion to

Figure 14: This position of the brake/control handle is recommended, because it allows a direct contact with the control line and precise control. Photo: Papillon

Figure 15: This position of the brake handle is recommended for beginners and should be chosen when manoeuvres are flown with an increased angle of attack (Big Ears, B-Stall). • Photo: Papillon

Figure 16: Riser

Figure 17: Speed system

Figure 18: Pulley on the front riser

help flying with “Big Ears” (see Chapter 2 on Flight Practice). The other risers follow behind, such as the B-risers (5).

The stabilizer line is attached to the B– or C-risers and leads to the outer end of the wing (the stabilizer). It is often marked in a different colour. Pulling on the stabilizer line can help to clear any cravat.

At the lower end is the carabiner attachment loop (7), where the entire riser is connected to the harness via a carabiner.

The individual riser layers are not only sewn together at the lower end of the riser, but there are also links between the A-, B-, C-, (D-) risers.

This constructive element gives the opportunity to shorten line levels to reduce the angle of attack. For this purpose, a small pulley (Figure 18) is attached to the front A-riser.

1.2.4 Speed System

Because we hang below the paraglider as a weight - similar to a pendulum – the result is always a state of equilibrium, where the force runs through the carabiner attachment loops (pivot point).

Therefore we have no mechanical means, for example by leaning forward, to noticeably change the speed of the paraglider.

But we have these different levels of lines, which are in a geometric balance to one another, the paraglider and us.

The whole speed system consists of a crossbar or loop with ropes, which run over pulleys through the harness to the carabiner, where they are secured to the risers with a tackle (brummel hook).

The operation of the system is done with the legs/feet. The front line levels are drawn down over the pulley proportionally with the ones behind.

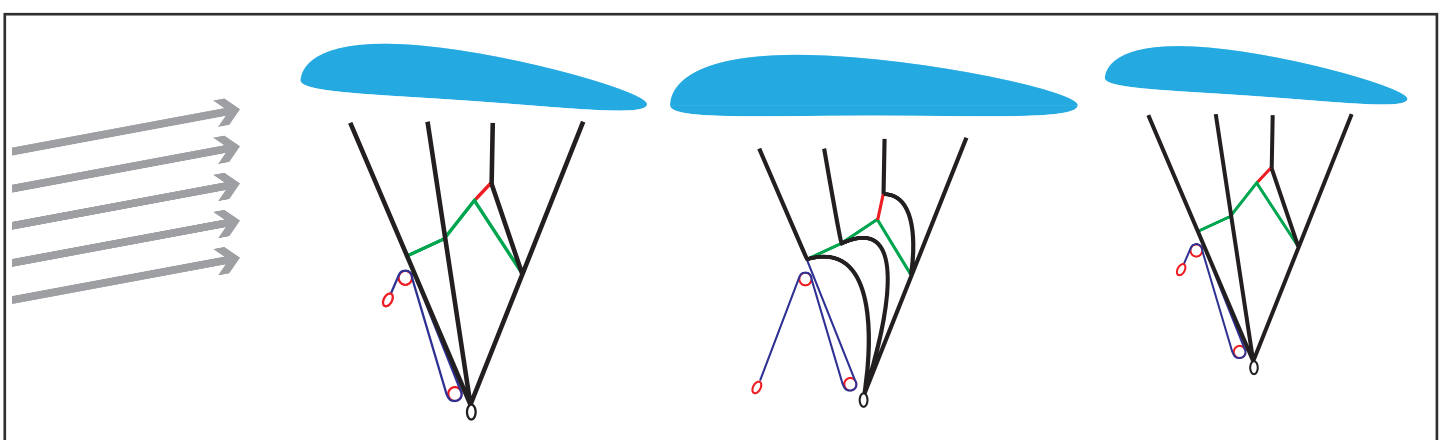


Figure 19: Operation of the speed system

In the accelerated state, the true airspeed increases. However, the rate of descent and the wings’ tendency to collapses also increases. Therefore the speed system should not be operated at a low altitude above ground and in turbulent conditions.

It should be adjusted individually for each pilot. The paraglider is fully accelerated when the two rollers of the pulley collide while the legs are fully stretched.

In order to stretch the legs, we have to sit first - and we do that in ...

1.2.5 The Harness

This „seat“ is attached to the risers with carabiners and via the lines to the canopy. The harness also offers storage space and mounting options for tools and other equipment.

Figure 20: Harness U-Turn RX 3

For a secure connection of the pilot to the harness, manufacturers have developed different systems to prevent falling out. The harness is put on like a backpack and the buckles are closed before flying. After the launching phase we sit as in an armchair and control the paraglider by weight shifting and arm movements.

Should a landing for once be somewhat harder, the so called protectors reduce the risk of injury. Approved harnesses must protect the back by tested airbag or foam protectors according to airworthiness requirements.

In a sampling inspection, the harness is dropped from a height of 1.65 metres to ensure the safety of the back protector. Additionally, the harness is tested on function, strength and behaviour in flight.

A pilot’s first harness should be one with a foam protector, because with it even harder landings can be endured without injury.

Harnesses are available in different designs, but the basic functional elements are found at any harness (Figure 20): leg- (1), chest- (4) and shoulder straps (6) surround us. The buckles (2) and the drop-out safety strap (3) protect us – when closed - from falling out. The centre or “drop-out safety” strap (also called „T-Lock-Safety-System“) prevents accidents, if the leg straps were inadvertently not closed at times (which should never happen!). Both carabiners (5) are our links to the risers.

Figure 21: High carabiner suspension: higher level of comfort, damped • Example: Woody Valley Wani

The closing of the buckles should always be done in a recurring pattern, to avoid forgetting the leg straps. For example, from „below“ to „above“, starting with the leg straps. All buckles must engage audibly and the carabiners must lock completely.

When buying a harness, attention should be paid on choosing one with the type of suspension best suited to your needs: „High“ comfort suspensions (= large distance between seat board and carabiner) transmit the movements of the canopy muted and directional control with body weight shifting is less sensitive (Figure 21).

In „low“ suspension harnesses (= short seat board carabiner distance) the movements of the canopy are more apparent to the pilot and the glider responds easily to the weight shift control (Figure 22).

Figure 22: Low carabiner suspension: more sensitive to control inputs by weight shifting, requires experience
Example: Advance Lightness 2

However, harnesses with lower suspensions should only be considered with more flight experience. Reclining harnesses with speedbags favour the twisting of lines and risers above the suspension after abrupt changes in direction, for example as a result of an asymmetric collapse.

Of course it is important that the harness is adjusted exactly to the pilot. He must be able to do both: run comfortably during the launching phase and then sit upright and relaxed during the flight. The seating position should also allow controlling the brake lines close to the body.

The chest strap should be set just loose enough to be able to lean forward while running and to allow using weight shifting to control the paraglider. A distance between the carabiners of approximately a forearms length (finger-tip to elbow) works best.

No part of the harness or its attachments should hinder the use of the reserve parachute!

Very loose leg straps can make it difficult to get into the harness after takeoff because the seat board may incline. In the worst case, the pilot may not be able to sit at all, which may affect the control behaviour of the wing and possibly lead to pain in the groin area. At worst, it could lead to a suspension trauma followed by a loss of consciousness when the blood sinks. However, sporty people are said to have about 15 to 20 minutes before a suspension trauma is developed, which should be sufficient time to reach a suitable landing site.

A very tight chest strap makes it difficult to accelerate with the body leaned forward (during launch) and to use body weight to control the glider (in flight). If the chest strap is extremely tight the spin tendency can be increased and the wings behaviour in a spiral dive may be adversely affected.

Therefore it is recommended to hang a new harness into a simulator to test its suitability and to adjust it to the pilot prior to flight with the help of a flight instructor.

Regular visual inspections of the straps and seams, the buckles, the protector and the speed system must be performed. Larger defects have to be fixed by a specialist company.

Even linking elements such as carabiners and quick links must be inspected periodically. Aluminum parts have to be replaced in case of damage (dents, nicks, loss of function) or when exceeding the manufacturer's specified period of use, since the strength of the parts may deteriorate in these cases.

1.2.6 Reserve parachute

The reserve parachute (or rescue) is integrated into the harness. It is like an insurance policy and used for our safety in an emergency. Openings of the reserve are very rare in the popular sports segment EN-A.

Canopy (1) and lines (central line (4), suspension lines (5)) of the reserve consist of an air-permeable and elastic polyamide that can endure opening shocks. Other components of the reserve are the apex (2), the skirt (3) and the bridle (6) (Figure 23).

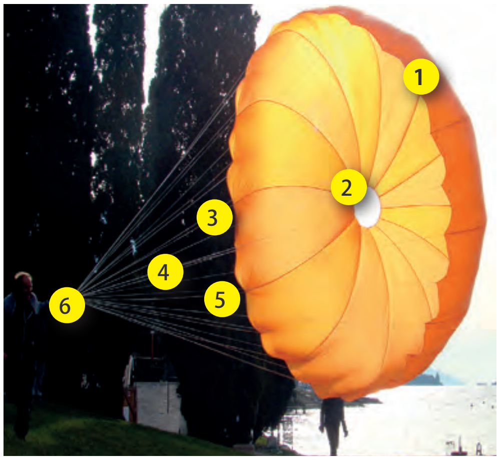


Figure 23: Round parachute

Uncontrollable round canopies are the standard rescue equipment. In addition to round parachutes there are also cruciform canopies (higher pendulum stability than round parachutes) and controllable rescues (for example Rogallo).

Modern rescue systems open in a few seconds, are pendulum stable and usually even allow standing landings due their low sink rates. In tests, the sink rate is determined with the manufacturer's specified maximum load.

Additionally the load is determined at a sink rate of 6.8 m/s. The total takeoff weight has to remain 20-30% below that load. Good parachutes sink with about 4 - 5 m/s, which corresponds to a jump from 1.5 metres in height.

The strength, rate of descent, trigger mechanism and proper packing procedure are inspected during the sample testing.

The reserve is delivered in an inner container, which is built into the outer container of the harness. We distinguish the outer container by front, side, top, back and seat container.

Generally, moisture and UV radiation should be avoided. While avoiding UV radiation is relatively easy (since the reserve is packed in an inner container, which sits in the outer container of the harness), the case is different with moisture.

Especially if you frequently leave the harness in wet grass and never ventilate the reserve, moisture can penetrate the fabric and cause mildew stains in the material. A rescue system that became damp needs to be spread out, aired in a shady place and newly packed when completely dry.

It is therefore useful to remove the rescue occasionally from the outer container and check it for moisture.

Before every flight, the safety pin/splint and the Velcro must be checked. Since Velcro usually increases its holding power over time, the rescue handle should be regularly released and reattached.

Manufacturers recommend packing the rescue one to three times per year. Specialized companies like the "LTB Wasserkuppe" offer a packing service.

Completely pulling out the reserve from the outer container is called compatibility test and must be performed with every new combination of harness and reserve under the supervision of qualified personnel before the first flight. The compatibility is dependent upon factors like the size of the reserve and the construction of the container.

The correct installation of the reserve is very important, because it determines if an unhindered opening would be possible.

When the handle is pulled, the splint must trigger first. This is only possible if the connection between the handle and the splint is shorter than the connection between the handle and the inner container. The connection between the release handle and the reserve must not be too long in order to ensure a powerful and targeted pulling away of the rescue in an empty space.

When using a front container, make sure that it does not cover the buckles of the harness so that a visual inspection can be carried out at any time.

Figure 24: Use of the reserve during a safety training

Preflight: Check the safety pin before each flight. Occasionally check the reserve for moisture.

Figure 25: Cruciform reserve U-Turn Cube
Photo: Papillon

1.2.7 Additional Equipment

To complete the equipment a CE approved (EN966) helmet is necessary. There is a wide variety of helmets available. Basically, full-face helmets are preferable to half-shell helmets, because they also protect the chin and face effectively. Gloves are also recommended - even in summer, because they protect the hands from the cold and especially from injury, which might otherwise occur for example during ground handling.

Figure 26: Helmet and gloves during ground handling • Photo: Marc Niedermeier

Figure 27: High-end variometer with GPS from Skytraxx

Figure 28: EN /LTF-A paraglider: U-Turn Emotion 3
Photo U-Turn

Tip: Your first equipment should consist of a paraglider with EN-A classification (Safety Class 2), a harness with foam protector and a CE approved (EN966) helmet.

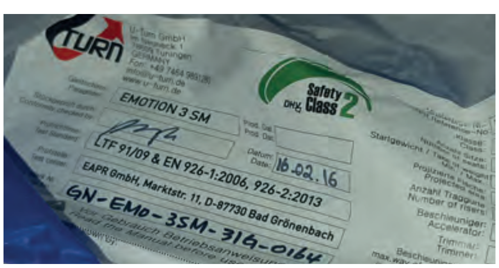


Figure 29: Inspection tag with certification in the canopy

Figure 30: Wings with different aspect ratios

A variometer is an extremely useful flight instrument. Its inner measurement system recognizes rising or sinking through the pressure decrease with altitude and displays that information audibly and visually. This particularly helps in locating updraft areas.

Thanks to the pressure measurement the variometer also serves as an altimeter. If one has calibrated the altitude and actual air pressure before the flight, the altitude can be displayed precisely during the flight. The remaining height above ground can be estimated significantly better than without such a barometric altimeter.

Another helpful flight instrument is a GPS receiver (Global Positioning System) to determine the current position and to record the flight. There are variometers with integrated GPS or individual devices in many different variants.

Recording flights is helpful to evaluate own flights or compare flights with those of other pilots. To know your own position also enhances safety.

1.2.8 Sample Testing

The high safety standards for modern gliders are monitored by sample tests.

Two test pilots have to fly a whole series of manoeuvres, simulate emergency situations and evaluate takeoff and landing characteristics in the lower and upper weight range of each paraglider size.

The classification is based on the worst result. In practice, the extreme flight behaviour may be much more critical than in the flight test due to wind, turbulence and pilot errors.

In addition to these test flights, paragliders are further tested before market introduction. Only after additional shock and strength tests and a detailed examination, an airworthiness certificate is issued.

The classification according to the EN/LTF-standard gives information about how much passive safety a paraglider offers.

The class EN-A is characterized by a maximum of passive safety and extremely forgiving flight characteristics. Extreme flight conditions require either no or significantly less effort than in paragliders with a higher classification. EN-A wings are suitable for pilots of all skill levels and prescribed for training.

Unlike EN/LTF-A wings, EN/LTF-D paragliders have very demanding flight characteristics and are therefore only suitable for pilots with a lot of practice in controlling abnormal flight conditions. Pilots must have significant flight experience in turbulent conditions!

Only after these tests would a particular paraglider model be given the certificate. It contains information about the LFT classification, number of seats, takeoff weight, manufacturer and the date of routine tests.

A copy of it must be visible in each wing and signed by the manufacturer to confirm that the individual paraglider corresponds to the sample tested for certification. The organization DHV additionally rates the flight behaviour of paragliders to the so-called Safety class (Figure 29).

Sample tests are also carried out for harnesses (functional testing, rupture tests, flight tests), as well as for rescue systems. Harnesses are tested in terms of their material strength and their back protectors. For reserves the strength, sink rate, trigger mechanism and proper packing method, as well as the previously mentioned load at a 6.8 m/s sink rate and the maximum permissible load are determined.

For beginners and occasional pilots the lower to middle weight range indicated by the manufacturer is recommended. Only professionals fly at the higher end of the canopy's weight range.

1.2.9 Measurement Fundamentals

The aspect ratio of a wing has a significant effect on its flight performance.

The slimmer a wing, the smaller the induced drag. In a rectangular wing, the aspect ratio is the ratio of wingspan to wing depth. The wing depth is also referred to as chord, which is an imaginary line from the leading edge of the wing to its trailing edge. A long, narrow wing has a high aspect ratio, meaning a long wingspan in relation to its chord.

$$\Lambda = \frac{b^2}{A} = \frac{b}{t}$$

b = Wingspan
A = Surface Area (projected)
t = (average) Chord

Figure 31: Calculation of the aspect ratio

An important note on the aspect ratio: wings with high aspect ratios also have disadvantages. They are much more sensitive to disturbances and require adequate pilot reactions at all times. This presupposes a high flying experience. Therefore, only paragliders with higher EN classifications have a high aspect ratio.

Since we have an elliptically shaped wing, we can also calculate the aspect ratio using the wingspan and the surface area. The aspect ratio equals the square of the wingspan divided by the surface area (Figure 31).

Unlike other aircraft, our wing is not particularly straight if we look at its leading edge. The strong curvature „distorts" the proportion of lift which counteracts the force of gravity.

Therefore, a distortion would also occur in all calculations and comparisons, if we would take the flat area as a reference. The correct reference is therefore the „projected" area. Unlike the depicted random shadow in Figure 33, the „top view" on the wing is taken (Figure 32).

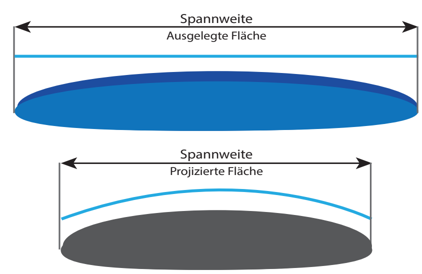


Figure 32: Same flat surface area, different projected area

The wing loading is calculated by dividing the total takeoff weight by the projected area. The takeoff weight consists not only of the pilot's weight, but also the instruments and equipment: the harness, reserve, helmet, clothing, footwear, beverages, (lipstick, cereal bars ...).

A typical paraglider has a wing loading of approximately 3 - 4.5 kg/m^2. By comparison, an Airbus A380 has a wing loading of about 450 kg/m^2.

$$\boxed{\textit{Wing loading} = \frac{\textit{Takeoff weight}}{\textit{projected area}}}$$

Figure 33: Shadow projection on the southern slope of the Wasserkuppe • Photo: Andreas Schubert

The higher the wing loading, the higher the airspeed and the rate of descent. A high wing loading also increases the wing's resistance to collapses, but more dynamic reactions have to be expected. In addition, the stress at the line attachment points of the wing increases.

The pilot's weight shall be within the range specified by the manufacturer. Otherwise loading and strength problems could arise as well as the mentioned dynamic wing reactions.

In modern wings the outer parts have a greater twist than the midsection. Thereby the stability and performance can be further enhanced and the flight behaviour (handling) simplified.

Figure 34: Geometric twist

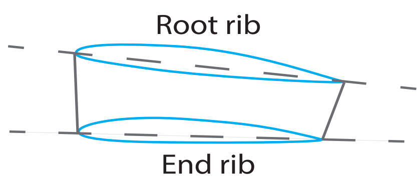


Figure 35: Aerodynamic twist


Figure 36: Aerodynamic heavier-than-air flight with a paraglider. By contrast, hot-air balloons use the principles of aerostatics. • Photo: Papillon

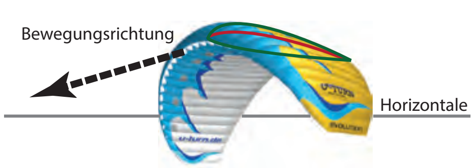


Figure 37: Our direction of movement when gliding in an air mass is forward and downward from an „elevated" starting point. • Illustration: Papillon

1.2.10 Wing Twist

Another design feature is the so-called twist of the aerofoil. It describes the twisting of the wing, which causes different aerodynamic conditions at the centre of the wing compared to the wing ends.

Basically, different proportions of the wing fly at different angles of attack in the air stream.

When skillfully chosen, these different angles cause an optimized lift distribution and/or better reactions of the wing to collapses. This twist can be achieved by two methods:

- In the geometric twist (Figure 34) the angle of the profile is modified for each cell/rib from the „root rib" to the „end rib".
- In the aerodynamic twist (Figure 35) the profile shape is modified to the wing tip.

Often even a combination of both methods is used.

1.3 Aerodynamics of the Paraglider

From the previous chapters, we now know the structure of a paraglider and have a first idea, why our wings are able to fly with us.

Contrary to our previous experience of limited two-dimensional movements on the earth's surface, there is another special dimension when flying:

We move with our paraglider in the three-dimensional space and also in an air mass. In addition to the horizontal component of movement we are used to there is a vertical component.

During a glide we have a forward speed, but also a sink rate as we are also moving down in an air mass. If the air mass moves upward or contrary to our desired direction of flight, it also carries us upward - or, with greater air mass movement, possibly even backwards relative to the ground as reference surface.

To better understand aerodynamics, we have to consider movement in the airflow only and forget about the ground for a while.

Here we go...

1.3.1 Forces on the Wing

Our direction of movement when gliding in the air mass is always inclined forward and downward from an „elevated" starting point (Figure 37).

Could we not sink, but only glide forward, we would have invented perpetual motion!

The necessary power comes from the downward movement. More specifically, the amount of height energy (potential energy from running up the training hill or an ascent by cable car or shuttle bus) is transformed into kinetic energy during flight.

To remain in the air „forever", we have to work with updrafts, as explained in the chapters on meteorology and flight practice.

The forward movement along the glide path (airflow direction) generates a lift force on the paraglider profile, which is directed 90° upward and forward of the airflow direction. However, it also results in a drag force, which counteracts this forward movement.

These two forces - lift and drag – combined produce the total (or resultant) force. If the resultant force is equal to our takeoff weight, which corresponds to the downward force of gravity, we are in a steady glide. All forces are balanced, there is no acceleration.

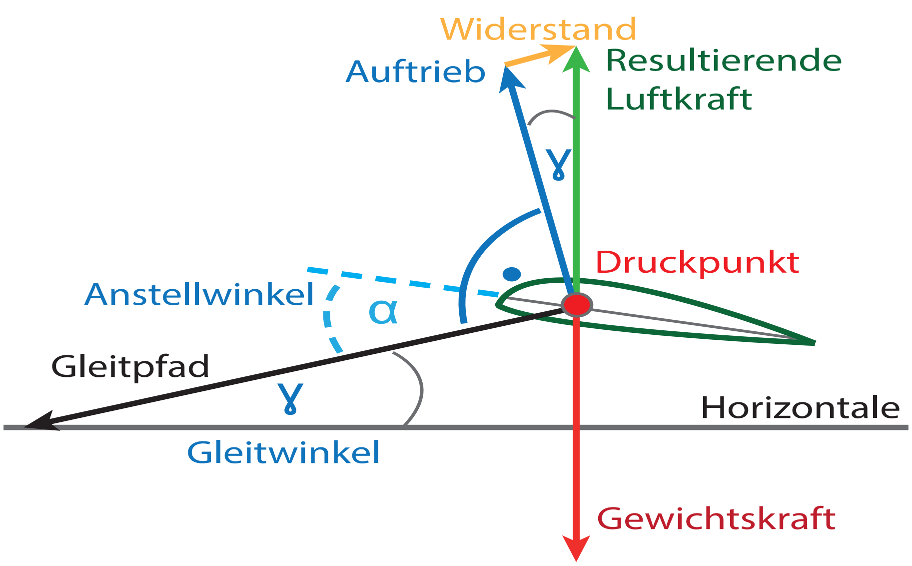


Figure 38: Forces acting on the wing profile

Figure 39: Strongly curved wing for a precision landing during the Paragliding Accuracy Worldcup
Photo: Marc Niedermeier

1.3.2 Speeds

As we have seen, the airspeed and sink rate are interrelated. We can influence these two speeds by different measures. The possibility of using a speed system has already been mentioned. It enables us to reduce the angle of attack (= the angle between the chord line of the aerofoil with the relative wind or glide path) and increase the speed in the direction of movement.

To decelerate we have our control lines - also called brake lines. The further down we pull the brake handle from the trim position (= best glide or 0% of brake line travel), the more we increase the curvature of the wing - and with it not only the lift, but also significantly the drag (the term brake line is therefore quite justified). It is noteworthy that drag is proportional to the square of speed.

The rule of thumb for the Conversion of km/h in m/s is: km/h: 4 + 10%.

1.3.3 Polar Curve

Both of these mentioned measures (pulling down the brake line/handle or using the speed system) cause a change in the angle of attack - and thus a change of lift and drag. The ratio of these two forces does not remain constant,

Example 1
In a head wind of 15 km/h and airspeed of 30 km/h, the glide ratio is halved, but the glide angle doubled.

Example 2
At a speed of 35 km/h and a tail wind of 20 km/h the glider is flying at 55 km/h above ground.

Figure 40: 100% brake pull, stall

(1) Stall point at 100% brake pull

(2) The still safe minimum speed, at approximately 50% brake pull. In an EN-A paraglider the brake handles are at about breast to waist level, in an EN-B wing about shoulder to chest level.

Figure 41: 50% brake pull, minimum speed

Figure 42: 20% brake pull, minimum sink speed

Figure 43: 0% brake pull, best glide speed

Calculate the glide ratio:
starting point height (h) = 1000m
flight distance (s) = 9000m

but changes for each angle. Because lift and drag affect the forward speed and the sink rate directly, we can determine the respective ratio by measuring these two speeds.

We obtain the characteristic speed polar curve for our paraglider: The airspeed is plotted on the horizontal axis and the rate of descent on the vertical axis.

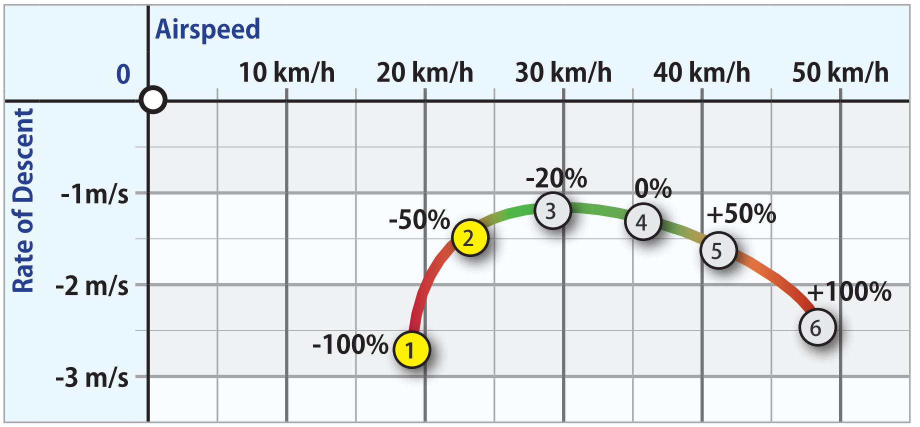
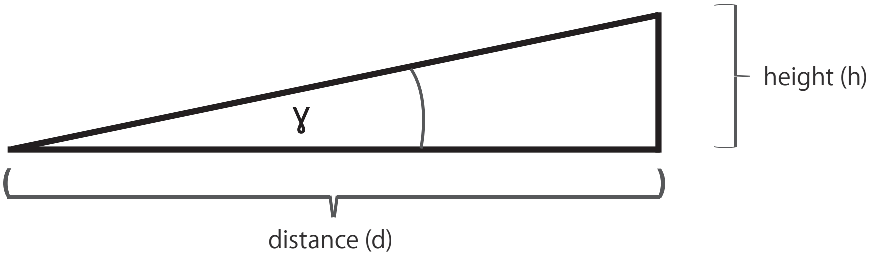


Figure 44: Speed polar curve of a paraglider, here with stall speed (1) and minimum speed (2). Graph: Papillon

Each point identifies a particular flight condition with the corresponding speed. Each flight condition corresponds to a determined position of the brake lines or speed system.

In Figure 44 you can see that, for example, in rapid, accelerated flight the sink rate increases markedly (red area, right part of the polar curve). Thus, the ratio of forward speed to sink rate is negatively influenced.

This has implications on the glide ratio. We cannot glide as far as, for example, with the "best glide" speed (point 4).



Glide ratio E:	E = Distance / Height = d/h
or glide ratio E:	E = Flight speed / Sink speed
Glide angle ɣ (gamma):	$\gamma = \arctan(\varepsilon) = \arctan(h/d)$

Figure 45: Relation between glide ratio and glide angle

The glide ratio is defined by the distance, which can be flown from a certain height.

Again, this is identical to the ratio of forward speed to the rate of descent. In slow flight, we also have a clear deterioration of the glide ratio: we fly slowly and sink faster.

Further characteristics can be seen at the polar curve. There is a point at which the ratio of speed to sink rate has a maximum value: the best glide speed (Figure 46).

This corresponds to the trim position of our paraglider, when we let go of the brake lines, or just pull them down slightly. In this position, our paraglider glides the furthest from a particular height.

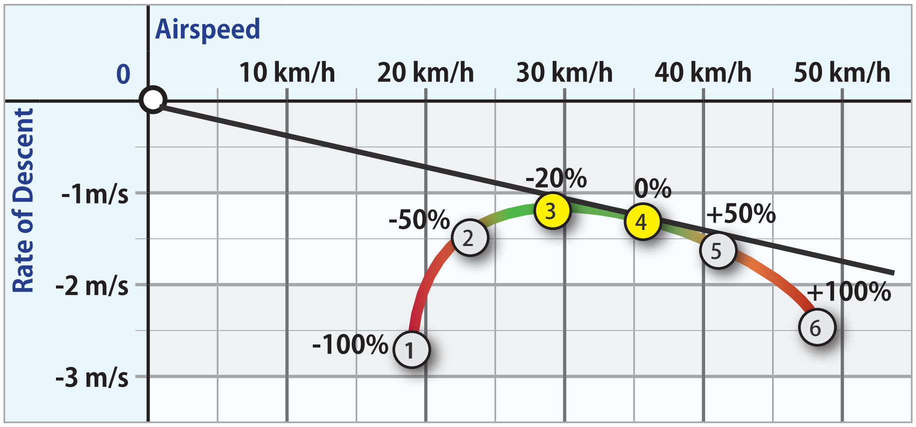


Figure 46: Minimum sink speed (3) and best glide speed (4). • Graph: Papillon

3 Minimum sink rate: At about 20% brake pull, the profile curvature is increased to a point where maximum lift is created and the sink rate is at its lowest. It is safest to fly a paraglider with 20% brake pull and that setting is also used when thermaling. It corresponds to a slight brake line pull of approximately 2-3 kg in ear to shoulder height.

4 Best glide: Modern canopies are set in a way that they fly the greatest distance at 0% brake pull (hands up). Therefore the trim speed is called the best glide speed.

Graphically and mathematically this point corresponds to the tangent from the zero point of the graph to the polar curve and shows the optimum. The best glide speed in the present example is at about 36 km/h.

Another characteristic point is where the vertical speed is smallest – the minimum sink rate (Figure 46): Again, there is an optimum.

Pulling down the brake handle to approximately the level of our shoulders will cause this flight condition. Depending on the paraglider, that is 10-30% of the maximum brake line travel. Thereby a force of around 2 kg is acting on the brake lines and the speed is about 29 km/h in the example shown. (When further pulling down the brake handles, the brake pressure needed increases significantly. At minimum speed, just before the stall, brake pressure is the greatest. In an incipient stall, the brake pressure is reduced noticeably.)

Although the glide ratio is not optimal near the minimum sink rate, we have reached the point of the largest lift. Generating more lift is not possible. The internal pressure is highest; the canopy has the best stability and is more resistant to collapses. This point of maximum lift and slow speed is also useful during the launch of the paraglider as it is a speed we can easily walk.

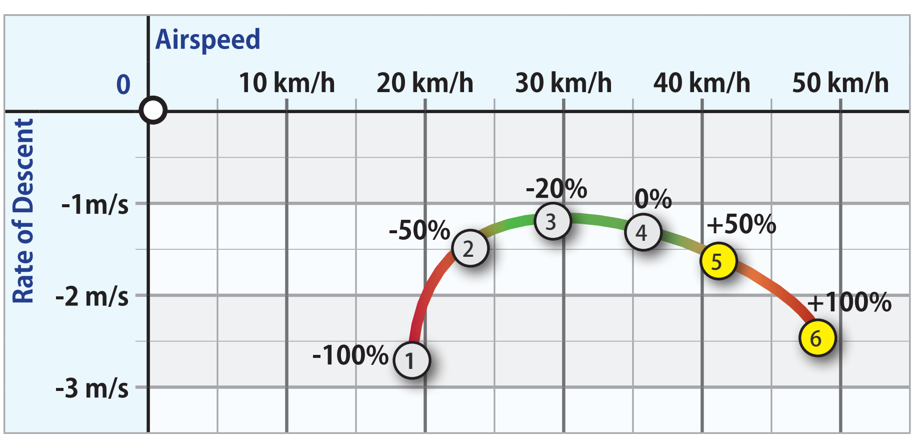


Figure 47: Slightly accelerated (5) and maximum speed (6). • Graph: Papillon

5 Slightly accelerated: With a slight acceleration using approximately 30 - 50% of the speed system travel, even beginners and leisure pilots are still able to fly safely.

6 With the maximum speed (Vmax) collapses are more likely. Therefore only experienced pilots should fly fully accelerated.

If we look at the polar curve (Figure 47) closely, we see it ceases at a maximum speed. It cannot fly faster for constructional reasons.

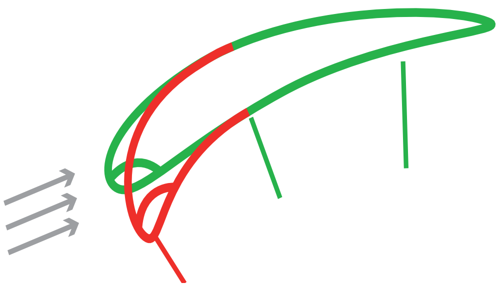


Figure 48: Risk of frontal collapses when the air strikes from above

To fly faster, the angle of attack would have to be reduced even further with the speed system. However, this would cause the airflow to strike the canopy from „above“ (Figure 48). The dynamic pressure is greater than the internal pressure, which causes so-called collapses (front collapse, asymmetric collapse).

Another striking point at the polar curve is the area of slow flight and the related high angles of attack. Again, the polar ends spontaneously.

Flying slower than at minimum speed is not possible. To generate lift, the air must flow around our wing.

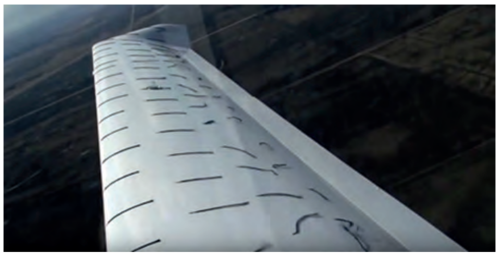


Figure 49: Stalled airplane wing

However, the air flow is heavily deflected at high angles of attack.

To maintain lift, the air flowing around the wing must remain close to the contour/surface of the wing, which is not sufficiently possible at high angles of attack: The airflow separates from the wing - from back to front.

Thus, the wing stalls - and our wing of soft, inflated material collapses. Since it has no fixed structure, it will fall backwards and simultaneously lose the remaining air. In this condition the remaining force is drag.

This unusual flight condition is extremely dangerous. In safety trainings above water you can learn to recover from this situation to normal flight. But this requires a sufficient height and great flying experience.

> NOTE: The minimum airspeed of about 25 km/h is reached with approximately 50% brake pull. Stalls are risked when attempting to fly even slower. Only test pilots fly at such low speeds to identify the wing behaviour at the stall point. Only once in each flight the brake handles are pulled down fully: when landing.

Therefore, any situation, which could cause such a stall, has to be avoided (see also the chapter on flight practice).

The safe flight conditions are within the green part of the polar curve - between slightly accelerated to brakes applied slightly.

The areas marked in red require our greatest attention. Yet we stall our wing once in every flight: when landing.

> Comment by Andreas Schubert: „After more than 5000 hours of flight I have never experienced an unintentional stall.“

Figure 50: Suction effect / negative pressure at the upper surface of the wing

1.3.4 Airflow and Lift

In the last section, the concept of airflow was noted. Provided that the air flows around our wing „neatly“, we fly. At the beginning of the chapter it was mentioned that airflow around a curved plate generates lift.

Looking at the airflow around the curved plate is noticeable that the air masses near the surface flow significantly faster than in the immediate vicinity. The overlying air masses remain largely unaffected.

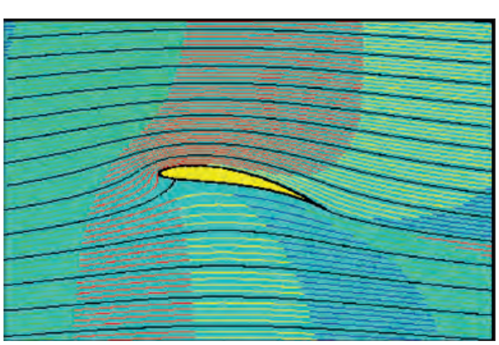


Figure 51: Airflow speeds around a profile

However, the air at the surface uses a trick in order to not "get stuck": It simply flows faster through the bottleneck. What enters in front, must come back out, there must be no congestion.

This phenomenon can be described as the Venturi Effect. For example, if the cross-section to get through is only half the size, the speed needs to be doubled.

This creates another interesting physical phenomenon, which has become known as the Bernoulli Effect. Each house that lost its roof in an autumn storm or each Cabrio with a closed bloated roof suffers from that phenomenon. Where a fast flow exists, a negative pressure arises (Figure 50)!

This is also how we get the annoying fly out of the car, when we open the car window slightly and the insect is simply sucked out. Exactly this suction also draws on our curved surface. It acts perpendicularly to the inflow direction and is strongest where the curvature is greatest.

In the flow simulation the significant acceleration (Figure 51) and the distribution of the low pressure area can be seen. Especially the acceleration simulation illustrates the enormous speed increase, which in turn is the cause of the pressure distribution around the profile.

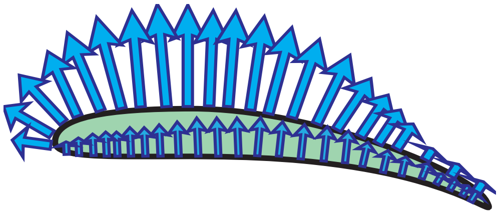


Figure 52: Pulling and pushing forces around a profile

1.3.5 Airflow and Drag

Unfortunately the airflow not only generates lift, but also drag, which acts against the direction of movement. Each drag portion is equivalent to a reduction in performance.

Drag can be divided into different types according to its cause:

The form drag results from the geometrical shape and pressure distribution around it: There is a different pressure of the side of the inflow direction and the opposite side. Depending on the shape and orientation of this form in the direction of flow, drag can be very high or extremely low.

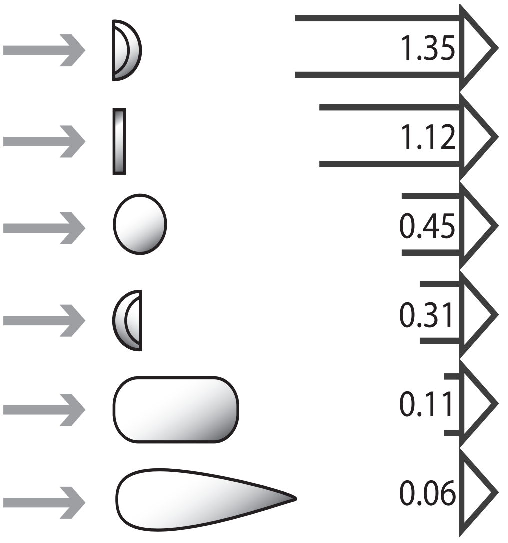


Figure 53: Typical drag coefficients Cd

The frictional drag is produced directly on the surface of the body in the flow: There the airflow is slowed down to zero, the layers of air above „rub“ with the lower layers. The type of attached flow - „turbulent“ or „laminar“ - has significant impact on the amount of drag produced.

Both types of drag together form the profile drag of the wing. This drag depends on the cross-sectional area, the velocity of the airflow, air density and its drag coefficient (Cd):

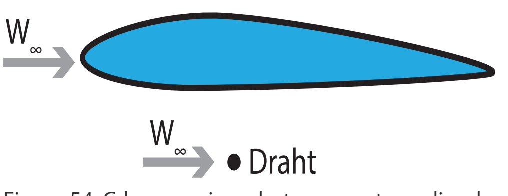


Figure 54: Cd comparison between a streamlined shape and a circular cross-section, e.g. wire or suspension line

The parameter Cd is a measure of the streamlined shape of a body and used to compare the drag of different profile shapes. To determine drag coefficients tests are carried out, for example in a wind tunnel.

The way lift is generated on a wing profile has a significant impact on the amount of the total drag: As already mentioned 2/3 of the lift is caused by suction on the top of the wing and 1/3 by pressure below the wing (see Figure 5). This pressure difference has the tendency to equalize.

This happens particularly easily on the wing tips: the high pressure under the wing flows to the area of low pressure on top of the wing. This causes the so-called wingtip vortices.

Figure 55: Wake vortex

These do not contribute to the lift, but still need energy. Thus an additional type of drag is induced, which is known as induced drag.

The higher the aspect ratio with a constant surface area and lift, the lower the induced drag.

Therefore, aircraft designers strive for high aspect ratios or other aerodynamic measures (like winglets) to reduce wingtip vortices: Especially at low speeds,

Figure 56: Smoke used to make the wake vortex of a paraglider wing visible • Photo: Skywalk

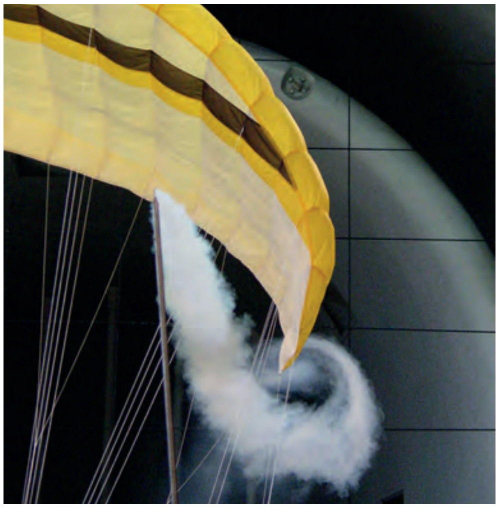


Figure 57: Vortex in the wind tunnel • Photo: Skywalk

Figure 58: Skywalk optimises harnesses in the wind tunnel • Photo: Skywalk

the wingtip vortices created are very strong and can constitute up to 50% of the total drag.

However, not all structural measures are feasible. Especially in paragliders a high aspect ratio is associated with disadvantages regarding the canopy stability.

As if we did not have enough drag already, there is another type of drag: the residual resistance, which is caused by all parts of the paraglider, which are not directly generating lift.

Especially the suspension lines form a great part of this residual resistance.

Even though the diameter of the lines may be very small - in the air stream they are bodies with a circular cross-section, which is a rather unfavourable aerodynamic shape with a high Cd value (Figure 54).

Also, the amount of linked lines and line attachment points leads to interference effects, which significantly increase drag.

Last of all, there is also the paraglider pilot in his harness suspended beneath all these lines. For the airflow this is a significant obstacle with many corners and edges, where many turbulences and erratic flow patterns occur.

Since there is no point in flying without a pilot, manufacturers try to further optimize harnesses, in order to reduce drag.

However, thereby also higher pilot's skills and more experience are required.

Harnesses with leg covers („reclining harnesses") as shown in Figure 58 produce less drag when properly adjusted, but may cause a twist in some flight situations. Therefore, they are not recommended at the beginning of a flying career.

1.3.6 Axes and Movements

In the last section, the observations concerned the different speed ranges in a steady glide.

However, this is only a part of the flight options: Of course there are more options to move the glider in the three dimensional space.

For orientation, the movement of the paraglider is described by the three axes around which it can rotate. They help to describe the basic rotational movements of a body in space (Figure 59).

Rotation about the longitudinal axis is called „to roll", about the vertical axis "to yaw" and rotation about the lateral axis is known as "pitch".

Each rotation about one of these axes can also influence the rotation about the other axes.

Thus, for example, a rotation about the vertical axis („yaw") also causes a rotation about the longitudinal axis: Since the part of the wing in the outside of the curve flies faster than the part in the inside of the curve, there will be a rolling movement in this direction!

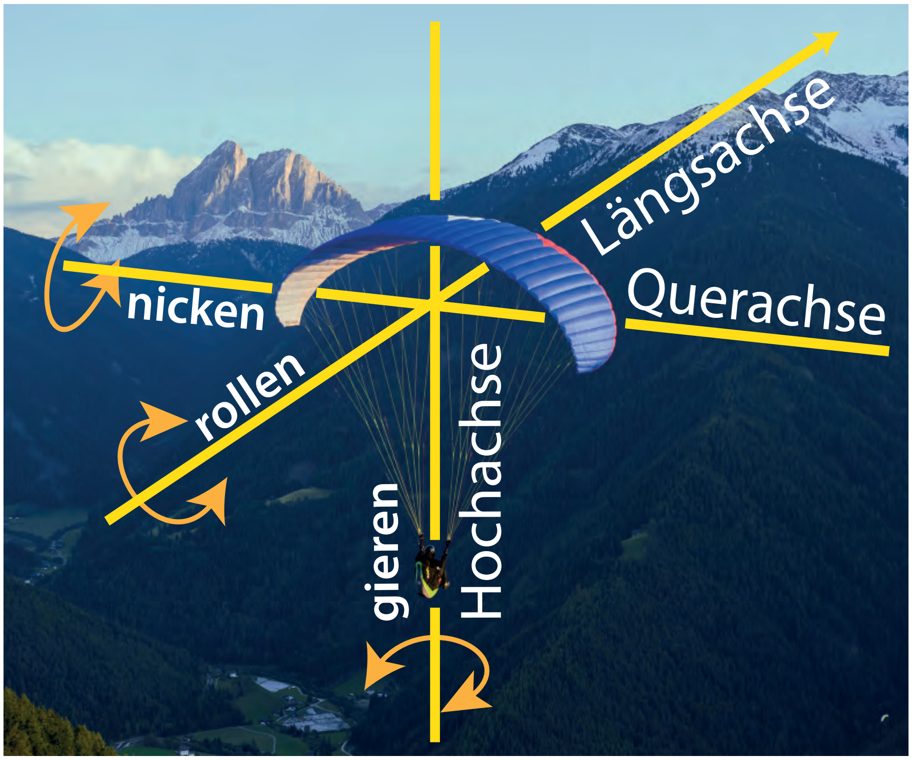


Figure 59: Axes and rotations • Graph: Papillon

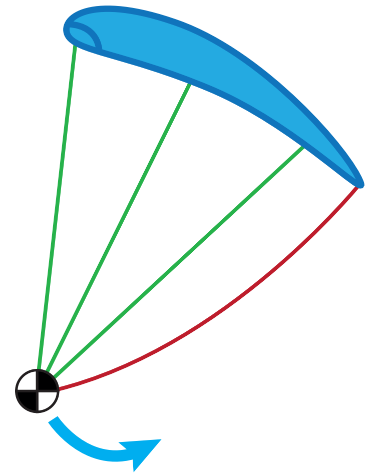


Figure 60: Pendulum effect of a paraglider

1.3.7 Pendulum Stability

A special feature of a paraglider is the high position of the (light) wing above the (heavy) pilot. This arrangement acts like a pendulum, which wants to return to the neutral position after any changes about the longitudinal and the lateral axis. Gravity counteracts the change in position.

The low centre of gravity of our pilot position is one of the reasons for the ability of the paraglider to get back into a state of equilibrium after small disturbances (rolling and pitching) without major action needed by the pilot.

1.3.8 Forces during Turns

In turns – besides the forces of lift, drag and gravity – there is also the centrifugal force, which increases the weight that needs to be lifted during the turn.

This weight acts perpendicularly to the lateral axis and leads to a higher speed (in the turn) and to a related higher sink rate. It is compensated by the resultant force (of lift and drag).

This amount of centrifugal force depends on the (total) weight and the radius of the curve flown: The tighter the curve, the greater the centrifugal force.

It also increases proportionally to the square of the speed.

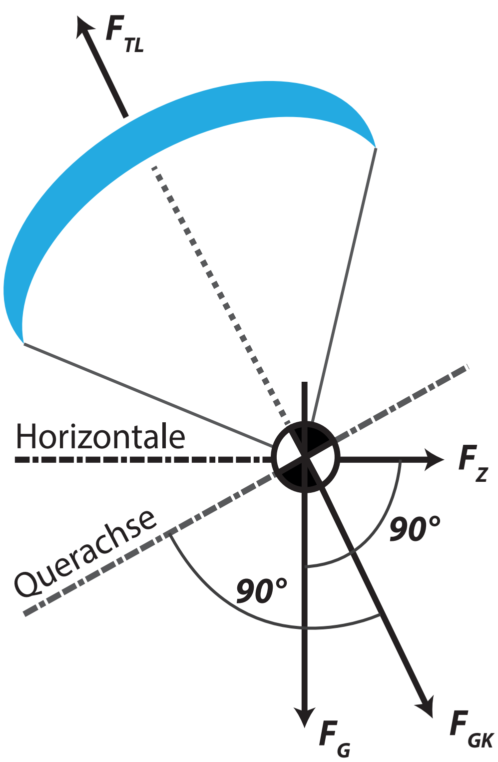


Figure 61: Centrifugal force when turning

Author of the chapters: Flight Practice and Meteorology

Andreas Schubert, born in 1970 in Fulda (Germany), is a certified pedagogue and flight instructor since 1993.

In 1990 he learned paragliding at the Flight Center Wasserkuppe. He participated in numerous national and international competitions and achieved excellent rankings. He won the German Championship twice.

„Thermaling for hours high above the countryside, only lifted by the force of the updraft, that is a special privilege. Paragliding is a beautiful outdoor sport," Schubert says today.

He is first Chairman of the hang- and paragliding association "Rhöner Drachen- und Gleitschirmfliegerverein Poppenhausen e.V.", which is the largest sports club in Germany with nearly 1,000 members and well known even outside the country's borders. He is the training manager, director and a shareholder of the Papillon Flight Schools in the Rhön (Germany), the Sauerland (Germany) and South Tyrol (Italy). He also uses his experience in flight sports to design and develop new paragliding equipment.

Figure 1: During the training, the instructor helps with the start check. • Photo: Boris Kiauka

To leisure pilots, who rarely fly in the Alps or other high mountains, we recommend guided paragliding tours. Thereby flight instructors make sure you have all the information necessary to assess launch and landing sites, explain you the available flight options and help you judge and understand the particular microclimate of the region.

Before starting the first thermal flight in a new terrain a simple glide down in still air is very useful to get to know the area.

2 Flight Practice

This chapter is meant to accompany your practical flight training and to explain the theory of flying: everything from launching, to rapid descent manoeuvres, unusual flight conditions up to the landing technique.

2.1 Pre-Flight

Inform: Before the pilot decides to fly, he has to check the weather information. The site selection will depend on the weather and wind forecasts.

Once the decision is made, the next detailed mental preparation is done at the landing field of the chosen flying area. We must always think through all the possible landing directions. In the Alpine valleys these are mostly two directions: into the valley and up the valley.

We consider where we will reduce our altitude and how the landing approach and landing may work in low or high winds. Especially beginners should gather as much terrain-specific information as possible from notice boards and/or the Internet and ideally ask one or better several pilots about their knowledge and experience.

When ascending with a cable car it is also recommended to focus constantly on the landing field. To become familiar with unknown terrain, it is ideal to do the first few flights in the quiet morning hours.

The launch site selection is just as crucial. Here too, inclination, obstacles, flight direction and again the weather conditions should be checked carefully.

If the launch site is well chosen, we pay attention to possible alternative landing fields in the direction of flight and obstacles such as power lines, equipment ropeways, houses or tree rows. Possible different wind conditions should always be considered.

Before launching the weather conditions must be checked again. Although a last look at the wind and weather reports on your smartphone does not replace your own weather observations, but it can help to avoid unpleasant experiences.

A paraglider which has been closely packed for an extended period of time should be inflated several times before the first takeoff to allow any folds of the fabric to smoothen out.

Particularly in higher-traffic areas as in the European Alps, pilots usually prepare next to the launch site first. Before putting on the harness, routinely check again that the reserve pin is in place. During the transport the pin might have moved, which could result in an unintentional opening of the reserve during flight. With your harness and helmet put on, you then go to the launch site.

We recommend that you visually inspect the harness, put it on, close all the buckles and clips, wear the helmet, prepare the variometer, put your gloves into the jacket and only then lay out the paraglider. In light winds we lay out the wing in an arch with the lines in the start direction.

The lines are sorted in the following order: control lines, (D-), C-, B- and A-lines. Pay particular attention to avoiding tangles.

2.2 The Launch

The paraglider is laid out symmetrically in an arch, so that the canopy behind the pilot can fill evenly from the centre.

The pilot launches the wing by a metered pull on the front risers with his arms stretched back and down and running against the wind.

Once the canopy is above him, he lets go of the risers and only keeps the control lines in hand.

He keeps running quickly, but not too fast, adapted to the wind situation. After a visual check of the canopy, for which he possibly applies some brake pressure to stabilize the wing, the acceleration phase begins. With big, bold steps and still arms the pilot reaches take-off speed.

He takes off the ground, but remains ready to run in order to react to an unexpected drop. Only with sufficient ground clearance he sits in the harness. The control lines are not released.

In flat terrains the pilot has to pay special attention to the acceleration phase. Large, long steps with little brake pull are ideal here.

In steep terrain, however, the pilot pulls the brakes gently to stabilize. The wing must not be allowed to shoot too wide forward because a collapse during the launch phase on steep slopes can be unpleasant.

Since take off happens very quickly in steep terrain, it is good if another experienced pilot can observe the launch and control it even in the early launch phase.

This all sounds rather complicated. However, in training all phases are discussed and trained several times, so that a certain routine is created.

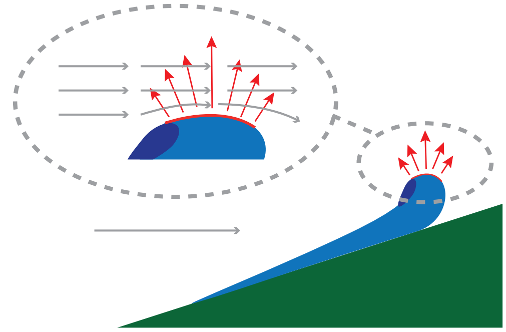


Figure 2: With an adequate launch impulse/input the canopy lifts off. The lifting force caused by the pronounced curvature of the profile at the leading edge is sufficient to lift a portion of the wing with its own weight.

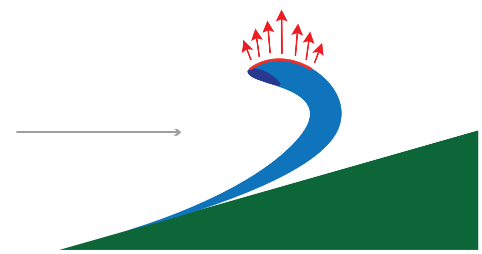


Figure 3: As the canopy rises, the effective curved surface increases and with it the lifting force until it is strong enough to lift off the entire weight of the canopy.

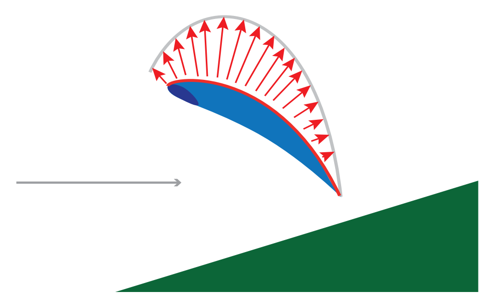


Figure 4: Thereby and by the air entering the cell openings in the canopy's leading edge the profile becomes fully inflated. The forward force of the aerofoil profile accelerates the canopy forward. In order to stabilize the wing above the pilot a slight brake pull is used.

2.2.1 The 5-point Pre-Launch Check

The 5-point pre-launch check must be performed before each flight. It is helpful to have the check conducted additionally by a second pilot (partner check).

1. **PILOT: Shoelaces tied? All buckles, straps and clips of the harness closed? Leg straps closed? Carabiner untwisted and closed properly? Helmet on? Radio on?**
2. **LINES: Lines free? A–lines on top? Risers untwisted? Speed system attached and untwisted? Control lines free and not twisted?**
3. **CANOPY: Laid out in an arch? All chambers open?**
4. **WIND: From the right direction? Is the wind speed right?**
5. **AIRSPACE: Free on all sides?**

Start Check: wind and airspace must be checked several times in alternation!

No start without a pre-launch check!

In flat terrain the impulse when launching the paraglider may be more powerful. After inflating and lifting the paraglider, perform a detailed visual check of the canopy. The running speed is reduced and adjusted to the wind situation during that visual check. In steep terrain launch the paraglider with less force and then a clear brake pull.

Figure 5: In forest aisles dangerous turbulences could form in crosswind conditions. Therefore, even a slight crosswind is critical. In calm weather, the takeoff distance to fly safely over the trees in front of the pilot further down the slope may be too short. • Photo: Boris Kiauka

2.2.2 Reverse Launch

In strong winds and challenging conditions a reverse launch is recommended, as this allows better control of the canopy.

Possible cravats and disorders of the canopy can be detected in the launch phase already. Thus, the control phase is simpler and an asymmetric rising of the wing can be corrected early on.

To perform a reverse launch, the pilot is facing the canopy and crosses the straps when clipping in. Always untwist in the direction in which the upper strap is attached to the harness. Before lifting the wing, hold the brake lines and make sure that they are not twisted or reversed!

Thereafter, take all A-risers in one hand. With the second hand, the rising of the canopy is controlled. To perfect the reverse launch technique, we recommend taking part in a reverse launch training.

Figure 6: A headwind of 5-10 km/h offers ideal starting conditions here. In stronger winds, turbulences leeward of the row of trees can be expected. With tailwind must not be started, because the distance needed until takeoff would be significantly increased and the updraft would be too weak to fly over the trees. • Photo: Markus Fiedler

2.3 Flight

Figure 8: Thermal flight over the “Lüsener valley”. Cumulus clouds indicate strong thermals. Photo: Felix Wölk

The amount of brake input used determines airspeed and direction. Turns are initiated by pulling down the brake handle (and thereby control line) on the inside of the turn and additional shifting of body weight in the same direction. The paraglider is slowed down on this side and - with some bank - enters a turn. Flying turns with weight shifting prevents the danger of flat spins. The brake lines should not be drawn lower than 50%, depending on the paraglider type.

Figure 7: Visual check before takeoff after lifting the canopy off the ground • Photo: Felix Wölk

The take-off distance increases at high temperatures and high altitude launch sites due to the lower pressure.

Ideally, the brakes are always applied slightly (about 10-20%) during straight and turning flight. This reduces the rate of descent and increases resistance to collapses.

In turning flight weight shifting or the so-called seat board control is crucial: The inner brake is only slightly more pulled, while the outer brake is slightly released. Usually about 10% brake pull remain on the outer wing and about 20-30% brake on the inner wing.

The following sections show possibilities and variations of this soundless flight adventure.

Figure 9: Practising ground handling is not only fun, but also increases safety during flights in thermals and ridge lifts. • Photo: Andreas Schubert

2.3.1 Ridge Soaring

Besides simply gliding from a mountain one can increase the flight time significantly soaring in upwind, because then the sink rate is compensated by the updraft.

The right-of-way rules and the soaring traffic rules are part of the theoretical training and play an important role.

The most important manoeuvres are 180-degree turns away from the slope. By shifting his body weight of the pilot initiates the turn. The brake pressure is increased somewhat on the inside of the turn and loosened by approximately the same amount on the outside.

Such turns are already practiced by student pilots in the first days of training. Training slopes in the undisturbed wind flow are particularly well suited to fly the first turns near the ground and to become familiar with the control of the glider. In the advanced courses ridge soaring is dealt with in more detail.

The entry-level paragliders of the new generation show remarkable performance characteristics in upwind and usually sink less than sophisticated paragliders with fast high-performance profiles. It is perfectly adequate to have a paraglider of the category EN-A for hours spent flying in upwind conditions.

Figure 10: With the Skywalk Mescal over the Alps (Lüsen) • Photo: Felix Wölk

2.3.2 Thermal Flying

Thermal flying requires the same basic pilot skills like ridge soaring. In addition, the thermal pilot should be able to fly actively. At the edges of thermals edge turbulences are created which can cause a collapse of the wing.

During first thermal flights it is advisable always to keep a slight brake pull of about 10-20%: The resistance to collapses is at its highest and the sink rate at its lowest. Now you can feel the ups and downs in the thermals and learn how to fly safely in it – that is: active.

When circling in a thermal with wind from a certain direction, the pilot must be careful not to be displaced. That means: When circling one has both headwinds and tailwinds.

With tailwind one flies much faster than with headwinds (wind shift). Strictly speaking, therefore, no circles are flown. To ensure the offset by the wind is not too large, the pilot must fly longer against the wind than with the wind. This makes it easier to centre a thermal, rather than "falling out" of it on the downwind side.

Wind shear turbulences have to be expected at the leeward side of thermals that are offset by the wind. If one gains a lot of altitude quickly in a good thermal, it must be ensured that the thermal is left in time to avoid being

Following the flight training towards your licence, we recommend further performance training courses with focus on thermaling and ridge soaring. Thereby you can learn the art of active flying under professional guidance without being exposed to the risks of autodidactic learning experiments.

Exercises such as flying flat, tight circles, big ears with and without speed system and small collapses will further increase your flying skills.

sucked up into the cloud. Otherwise the pilot is likely to become disoriented, panic and commit more flight error as a result.

If the lift is so strong that flying into a cloud would be unavoidable or if the pilot wishes to terminate the climb for other reasons, it is advisable to use Big Ears or another rapid-descent method (see 2.3.3).

Active flying (Figure 11): The pilot stabilizes his paraglider actively with corresponding control line use to counteract oscillations.

Comment by Andreas Schubert: „Thermaling is the supreme discipline of paragliding. It really is so beautiful that it may take your breath away. Thermaling up and seeing the mountains from a bird's-eye view is a fantastic experience. However, this type of flying is not without risk.

The first thermal flights may be flown only with safe EN-A paragliders. They compensate for pilot errors.

Collapses are rare with EN-A paragliders and occur (almost without exception) only when the pilot is not flying actively yet. The first thermal experiences should be made under the guidance of experienced instructors."

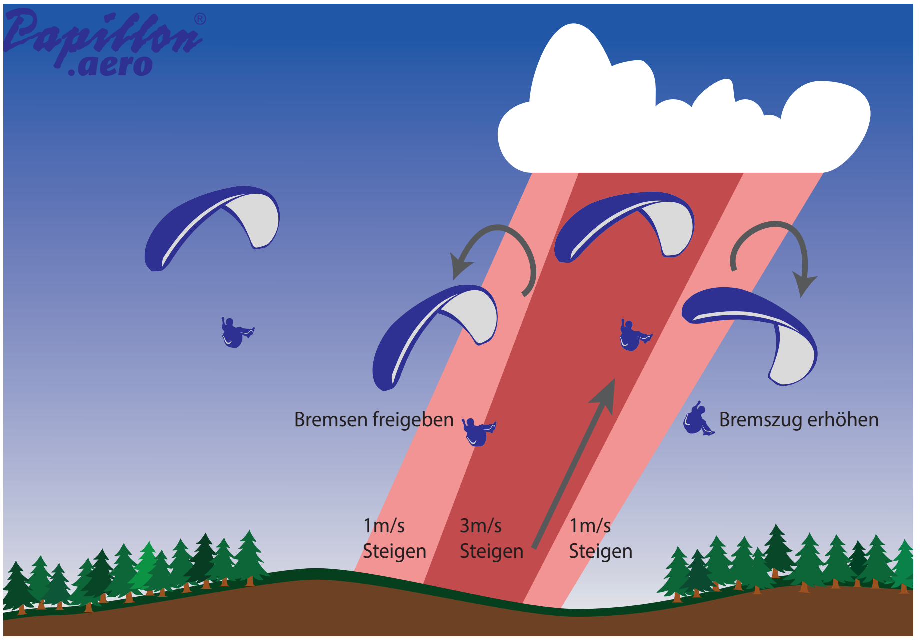


Figure 11: Flight through a thermal. Flying active means to keep the canopy always directly above you. • Illustration: Papillon

Releases the brake lines when entering the updraft, because otherwise the angle of attack increases. (When the critical angle of attack is exceeded, a stall would occur.) In thermals the pilot flies full circles or with the minimum sink rate (slight brake line pull) to achieve maximum gain in altitude. The paraglider then generates maximum lift and has the highest canopy stability.

When leaving a thermal the pilot uses further brake input in order to avoid that the canopy dives forward and oscillates (a too small angle of attack could lead to a frontal collapse). „Active flying" means to respond to changes in the canopy, e.g. caused by turbulence, in order to keep the canopy's position always directly above the pilot.

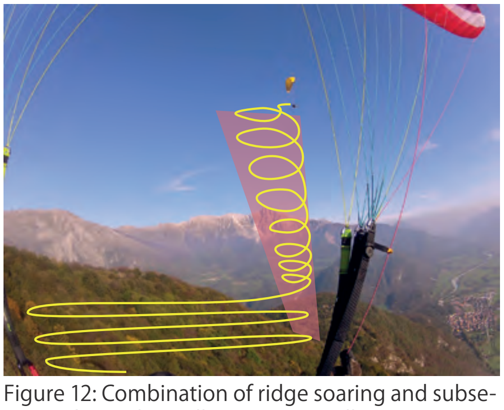


Figure 12: Combination of ridge soaring and subsequent thermaling • Illustration: Papillon

Advice on thermal flying:

- An increased sink rate and turbulent air signal to the pilot that he is approaching a thermal updraft.
- When the variometer begins to signal lower ascent rates after the strongest lift, the pilot should start circling in the thermal..
- In the headwind part circles must be extended and in the tailwind part circles must be flown closer.

2.3.3 Rapid Descent Methods

2.3.3.1 The Spiral

Figure 13: Spiral as seen from above. Recover in good time! The B-Stall is preferable as a rapid descent method. • Photo: Felix Wölk

The spiral is considered an extreme manoeuvre and should be flown only under expert guidance above water. Owing to the high physical stress the manoeuvre is only recommended for experienced pilots.

> The spiral should be used only by experienced pilots with fast paragliders. Leisure pilots use rapid descent methods such as big ears or the B-stall when necessary.

Entry:

For a first circle a turn is flown tighter with body weight and inner brake. For the 2nd circle the bank is increased. The outer brake line is also pulled with increasing speed. In the 3rd circle the wing banks into the spiral and reaches sink rates of about 10 m/s.

Spiral phase:

With the outer brake (10 to 30%) the pilot can control the bank angle, the sink rate and the speed during the manoeuvre. Thereby a G-load of about 2.5 to 4 acts on the body.

Note: The wing should not be forced into the spiral too quickly as this could cause a stall on one side with extreme sink rates, the wing could even flip over.

> Around 70-80% of all pilots fly about 1-2 weeks per year only. For this pilot group neither the spiral nor safety trainings are recommended.
>
> Only ambitious pilots with significant thermaling experience after several hundred flights should consider a technique and safety training above water.

Recovery:

To recover from a spiral release the brake pressure on the inner brake, neutralizing the body weight and increase the pressure on the outer brake. Before being fully recovered, the paraglider will continue to turn for one or two more circles. The speed and bank angle will be reduced.

Figure 14: B-stall. • Photo: Markus Fiedler

Note: Trying to recover too quickly can cause a collapse when the wing swings behind the pilot. When recovering too slowly, a full recovery might not be achieved and the rapid loss of altitude may continue. If that happens, the dynamic may be reduced by applying brakes on both sides. The brake pressure increases during the manoeuvre because of the increased G-force. If the recovery is not possible, deploy the rescue!

2.3.3.2 The B-Line Stall

This manoeuvre offers the possibility to descend comfortably and safely: By pulling down the B-risers the wing is folded along its lateral axis and thereby stalled, which causes a sink rate of about 6 to 9 metres per second.

Entry

The pilot keeps the brake handles in his hands. He sits up and at the same time takes the B-risers. He has to make sure that really the B-risers are taken and not the C-risers. This could happen if a pilot incorrectly starts counting from the trailing edge instead of the leading edge of the wing. Some manufacturers label the risers in order to avoid confusion.

Figure 15: Mike Küng performing a B-Stall with the Skywalk Masala 2 for the Paraglider Practice Test

The B-risers are pulled down slowly, thus slowing down the entire paraglider. After a pull of about 15-20 cm the stall occurs. Slowed down like this, the canopy barely falls behind the pilot with an increasing sink rate.

The Manoeuvre

Look immediately upwards, if the desired B-stall occurred. Then look down to control the loss of altitude and the area below you. Then alternately look upwards and downwards.

Should an atypical deformation of the canopy occur, immediately release the B-risers and recover from the manoeuvre. A slight turning tendency is normal, because the manoeuvre often cannot be initiated 100 percent symmetrical. The wind may also have an influence. If the change in direction feels unpleasant, just recover and repeat the manoeuvre.

Recovery

By a brisk - but most importantly symmetrical - release of the B-risers, the manoeuvre is completed. The canopy dives forward to reattach the airflow and end the stall. Do not prevent this pitching forward by braking. Pilots with an active flying style tend to stop this desired pitching moment.

The difference of the forward pitching moment after a B-stall and the pitching moment after a thermal flight is that the paraglider needs to accelerate after a B-stall while it simply swings back and forth in the turbulences caused by thermals.

Do not pull the C-risers! During a correctly executed B-stall the paraglider simply decreases, however, when the C-risers are pulled, the wing forms a negative profile and flies backwards with up to 20km/h or even more.

While this may be controllable by experienced pilots, untrained pilots could be overwhelmed by the canopy diving forward and might miss to counteract that tendency by an appropriate pull on the brake lines.

2.3.3.3 Big Ears

Another important and in many cases recommended rapid descent method is called „Big Ears“ (Figure 16). By pulling on the outer A-lines, the „ears“ of the paraglider (usually two to four cells) are collapsed.

The sink rate increases, while the airspeed remains approximately constant.

This can help, for example, to escape cloud suck, whereas in a spiral the paraglider would still remain in the area of suction under the cloud.

The manoeuvre is terminated by releasing the A-lines. Since the wing loading increases and the airspeed remains roughly the same due to the greater drag, the stall speed increases. Changes in direction during the manoeuvre are performed with weight shifting.

EN-A wings show an unproblematic behaviour during this manoeuvre. With EN-B wings, big ears should only be applied in connection with using the speed system. The reopening also requires some skill in order to avoid slowing down the wing to stall speed. Most EN-A gliders of the new generation facilitate big ears with special big ear aids.

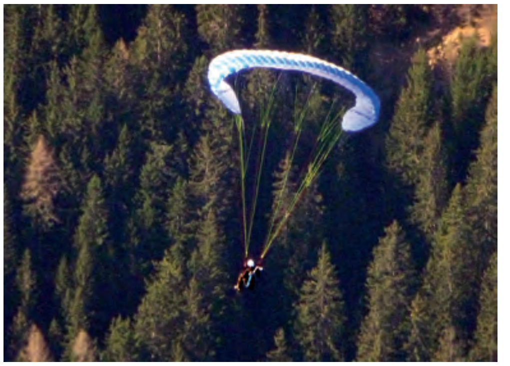


Figure 16: Big ears. Steering is done by shifting the body weight. • Photo: Papillon

2.3.4 Extreme Flight Situations

The paraglider has some peculiarities that distinguish it from other aircraft owing to the absence of a rigid structure. This includes (with partial deformation and deflation of the canopy): collapses, stalls, full stalls and spins.

Figure 17: A provoked collapse for demonstration. With a 50% collapse like here the wing can still be flown straight and would allow a “standing” touch-down. Collapses like this are extremely rare with EN-A wings and only occur in severe turbulence. Photo: Markus Fiedler

2.3.4.1 Collapses

Collapses occur with negative airflow. There are asymmetric and front collapses that are, for example, caused by the turbulences at the edge of a thermal. The folded area is opened independently from the inside by transversely flowing air through the pressure equalization openings.

Nevertheless, the pilot should counteract by pulling the brake of the side that is still open to avoid the paraglider turning away. This is particularly important when flying near the slope. A collapse is the only extreme flight situation for which a response is desirable even by beginners.

Shifting the body weight to the open side is sufficient in most cases to stabilize the paraglider. Only when there is a turning tendency in the direction of the folded side, additional braking on the open side should be used to counteract the turning.

For all other extreme manoeuvres (that can be practically only caused by pilot error): Hands up to immediately release any brake pressure.

Asymmetrical collapses with the pilot swinging forward (and the canopy backward) are extremely rare. If it happens: Do not pull the brake. Only when the canopy dives forward and the pilot swings backward a counter-control by pulling the brakes is desirable.

In the case of a collapse with the canopy diving forward while having a strong turning tendency, a quick pilot reaction is useful to avoid a change of direction and to minimize the loss of altitude. Paragliders of the categories B or C are more demanding and require active counter-measures when collapses occur.

The modern paragldiers of the new generation compensate asymmetrical collapses of about 50% with no or only a slight change of direction. In addition, they also open quickly. Even in massive collapses affecting a large area of the wing they usually turn only about 45 to 90° until re-inflation. Such inflation behaviour is called „independently, immediately“. The loss of altitude is low.

When using the speed system, the angle of attack decreases and the risk of collapses increases. Should the wing collapse in accelerated flight, the acceleration must be stopped immediately!

Paragliders should never collapse over 50%. The pilot is clearly overburdened in such a case, both with the paraglider and the conditions. After re-opening, please land! Asymmetrical collapses with safe paragliders indicate a lack of thermaling experience. Please land and continue flying later when the conditions are calmer. Further thermal and soaring training with a flight school is recommended.

When a collapse occurs during accelerated flight, the reactions of the wing will be stronger. For example the turning tendency towards the collapsed side is increased.

Collapses with EN-A wings are extremely rare and usually announce themselves in turbulent air. It is unlikely that a canopy collapses without having indicated the turbulent air previously with the ears or wing tips.

Since the collapsed side usually opens in fractions of a second (so fast that no pilot reaction is necessary), there is rarely an accident resulting from collapses, unless caused by serious pilot error.

A tremendous development of equipment took place in recent years for the benefit of flight safety, even when flying in thermals.

Collapses in training

With several hundred flights and some dozen hours of soaring and thermal experience, a safety training above water is recommended for ambitious pilots. In particular, a transition to a B- or C-glider requires such training.

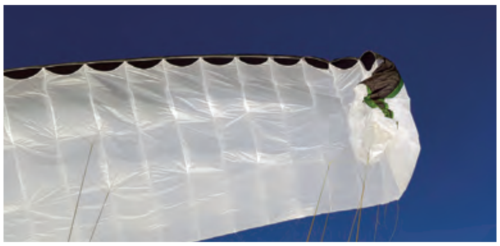


Figure 18: Collapse with cravat • Photo: Papillon

Frontal Collapse

In frontal collapses symmetrically pulling both brakes is enough to open the cells again.

Since a frontal collapse is a stall, the brakes need to be released after the re-inflation (usually within a few tenths of a second), so that the wing can gain speed again and continue flying. The new, safe paragliders open independently in emergencies without active behaviour of the pilot.

Andreas Schubert: „There is an exam question (for the German paragliding licence) that claims a cravat could be resolved using the stabiliser line. However, I have not seen any case where the stabiliser line had actually solved the problem.

Therefore, I recommend the following strategy: Collapse the side with the cravat using the risers. The induced collapse is unproblematic and easy to control with taking countermeasures. This method should also be applied when the pilot accidentally started with a cravat already.

Collapses with cravats (Figure 18)

If a collapse is so severe that a cravat occurs, it cannot open anymore and the pilot has to deploy the reserve parachute. Fortunately this is extremely rare.

For ambitious pilots at sufficient altitude the following ways may be tried to remove the cravat:

- Full stall: The falling behind of the canopy can release a cravat at the leading edge of the wing. The pilot should be sufficiently high and must have appropriate experience from safety trainings.
- When the cravat occurred at a wing tip: Pulling in the stabilizer line while controlling flight direction may help. The stabilizer is usually suspended in the B- or C-risers and marked in a different colour.

2.3.4.2 Full Stall

The stall is recognized by the decrease of wind noises and by a high rate of descent (5 - 20m/s).

There can be several causes: pilot errors (too much brake application, changing wind conditions or deficiencies of the canopy (high air permeability due to aging). The pilot should allow the wing to re-establish airflow. All modern paragliders recover independently. To do so, the pilot must release the brakes (but keep them in his hands), so that the wing can accelerate again.

2.3.4.3 Deep Stall

If the wing stalls but is still filled with air, you are in a deep stall.

Strictly speaking, this is not a flight because no airflow is attached to the canopy. Further brake pull leads to a full stall, a stall with partial emptying of the canopy, forward folded ears and backward flight.

To end this flight condition, the pilot also has to release the brakes quickly, but not too fast. From the backward flight the wing dives far forward. Pulling the brakes can prevent a collapse.

EN-A gliders must have an unproblematic stall behaviour. That means, they have a long control travel, an increasing brake pressure before stalling and no spin tendency.

Unintended stalls almost exclusively occur with incorrect landing setups and approaches, when the pilot pulls the brakes to early on final approach.

Therefore, when landing, make sure only to apply the brakes fully at an altitude of about 1-2 metres. Stalls are only practiced at high altitudes and only in safety trainings above water.

The deep stall tendency increases with a wet canopy, high air density and low temperatures.

2.3.4.4 Partial Stall

Figure 20: Intentional stall. • Foto: Papillon

A stall can also occur on one side only by a rapid strong pulling on one brake.

The wing enters a sudden, highly accelerated rotation around its vertical axis, with almost no bank. This uncontrollable flight condition is called (flat) spin. The pilot releases the brakes.

The secure paragliders of the new generation end a spin independently and immediately. In a stable spin with sufficient altitude, the manoeuvre can be terminated with a full stall, at a lower altitude you have to deploy the reserve.

Andreas Schubert: „In more than 5000 hours of flight time, partly under extreme conditions and even with high-performance wings, I never experienced an unintentional stall, spin or deep stall.

I have never experienced a collapses of the entire wing. Collapses, stalls or the use of the reserve parachute are the exception and not an integral part of thermaling.“

Figure 19: Ground handling training with Mike Küng, Wasserkuppe. It is useful to practice the full stall during ground handling to learn how it feels. In the air the still safe minimum speed is reached with an approximate brake pull of 50%. Except when the canopy dives forward, there is no reason to pull the brakes more than that during the flight. The only time you use full brakes is for the landing. Photo: Papillon

EN-A paragliders have no spin tendency. They even “forgive” pilot errors and have an enormous safety potential. Before they stall on one side only, they enter a spiral.

Tip: Always turn with both shifting the body weight (seat board control) and pulling the brakes.

2.4 Landing

The landing should always be upwind. At a safe altitude the wind direction and strength are judged and the landing pattern (Figures 22, 23) and approach are planned.

Visual clue to clear obstacles: If an obstacle clearly moves towards the background or maintains its position, a safe overflight is not possible.

The normal landing pattern begins at the position, where any remaining excess altitude is decreased, in case of a left pattern by flying left circles. The downwind, base and final legs follow. Final approach is into the wind.

Throughout the entire pattern the paraglider is flown with a slight brake pull for maximum canopy stability. The landing spot serves as a reference point and is constantly observed.

Figure 21: Ready for touchdown • Photo: Papillon

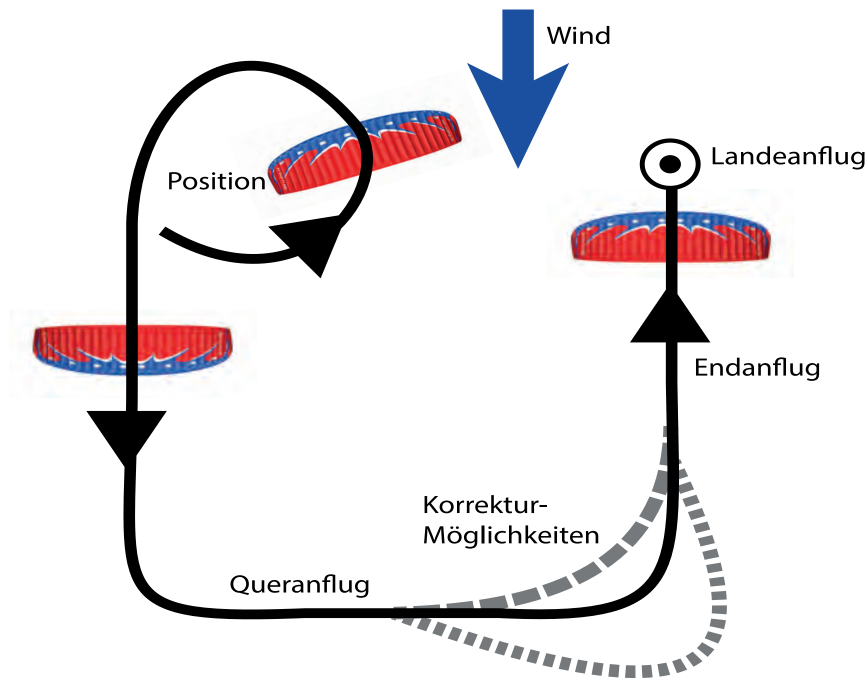


Figure 22: Standard landing pattern. • Illustration: Papillon

On the approach legs you have good correction possibilities (dashed lines). So it is possible for many student pilots to land on a spot as small as a towel or within a few metres of it only after the first flights.

The pilot must straighten up in the harness at least 5 metres above ground. In about one metre above ground he fully pulls the brakes to perform a landing stall in order to reduce the rate of descent and airspeed. The touchdown is simplified and standing landings are easily possible. A pilot should not pull the brakes too early.

Landing: In about 1 to 2 metres above the ground you first pull the brakes approximately 50% and then fully after a short moment.

Especially in the final approach it would be dangerous if a stall occurred in 3, 4 or 5 metres already. The best landings are those with a nice flare. The final approach is carried out in trim speed if possible.

In thermal conditions a final approach with maximum canopy stability (10-20% brake pull) is recommended.

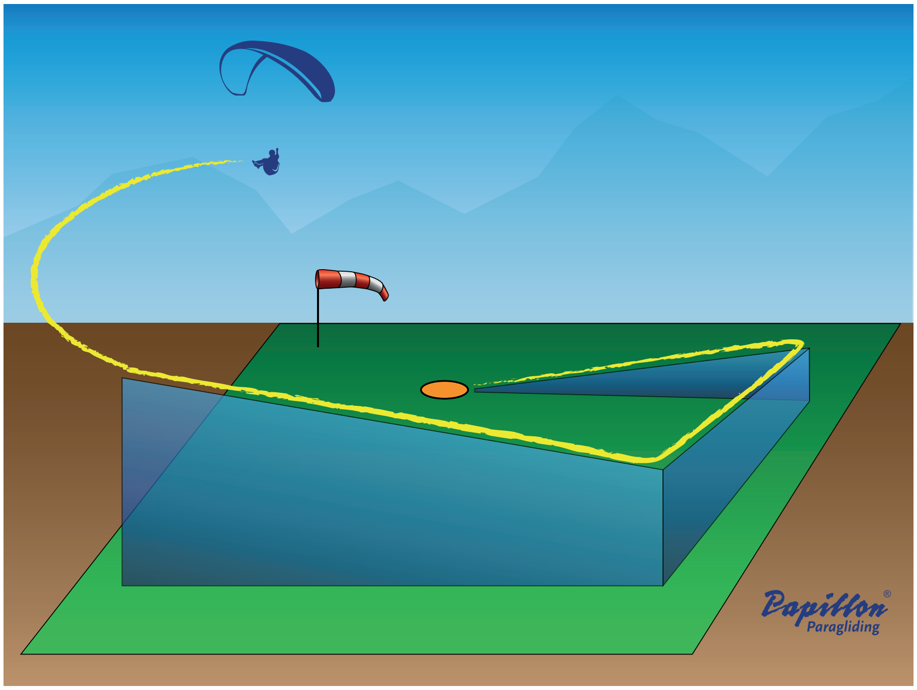


Figure 23: 3D model of downwind, base and final approach • Illustration: Papillon

2.4.1 Strong Wind Landings

In strong winds you fly several base legs before the landing point with semicircles into the wind (called an “eight setup”).

Begin a short final approach into the wind in about 10 to 20 metres above ground using slight brake pressure.

Do not turn with the wind as airspeed and wind speed add up. A landing at a high ground speed could be dangerous.

If the wind is extremely strong, EN-A paragliders can be flown with big ears until touchdown without further braking. After touchdown the pilot turns around quickly and brings the canopy down by using the C-risers in order to avoid being dragged across the ground.

2.4.2 Landing on Slopes

A landing on the slope is always done sideways to the slope and never against it due to the increasing risk of injury. Hang landings require some routine. At the beginning of the flying career areas with large landing fields are recommended.

2.4.3 Top Landings

Landings at the launch site (Figures 18 - 20) require wind or thermals. Therefore, they are recommended only for experienced pilots with lots of ground handling experience.

Pictures 24-26: Top landing in Lüsen, only for very experienced pilots! • Photos: Papillon

2.5 Special Situations

Figure 27: If landing in a forest becomes unavoidable, the pilot must fly frontally into a tree and then secure himself on a stable branch. He has to catch attention (through calls, a whistle, the cell phone) and wait until help arrives. Almost always pilot and paraglider survive such a tree landing unscathed. Therefore, a landing in a dense evergreen forest is preferable to a landing on a small clearing, in a lake or on a steep slope. • Photo: Norbert Fleisch

When a moderate tailwind alternates with thermal detachments from the front, do not launch, because the circumstances indicate a lee situation.

If the landing area is in a hollow, anticipate an increased sink rate in the final metres because of the strong wind gradient.

When you are on final approach and the windsock suddenly displays a light tailwind, maintain the landing direction nevertheless, use a stronger impulse when pulling the brakes and prepare for having to run more than usual after touchdown.

When you notice that the headwind at your altitude is strong, but the windsock at the landing site displays only a weak wind, expect a decreasing airflow rate on your glider and therefore don't pull the brakes too much.

If you get surprised by a rain shower due to inadequate flight planning, leave the precipitation area as soon as possible, but without carrying out a rapid descent with the wet canopy. The brakes should only be used carefully. Accelerate with the speed system to compensate for the increased spin and deep stall tendency.

Figure 28: If a pilot has to land in water, the buckles of the harness have to be opened shortly before landing so that the pilot can slip out of the harness and swim away after touchdown.
Photo: Norbert Fleisch

Should a control line become unusable for some reason, the paraglider remains controllable through the rearmost risers, however with significantly shorter control travel.

When you notice after takeoff that the wing clearly pulls to one side, because several C- and D-lines are tangled together, correct the direction by weight shifting and a gentle brake pull on the other side.

Only with a larger distance from the slope and ground you should try to loosen the tangle by pulling on the main lines. If this attempt fails, refrain from abrupt steering movements and fly to the nearest suitable landing field. Turns should be made in the direction of the tangle, if possible.

If the glider enters a spiral dive after an extreme flight condition, the rescue must be deployed immediately. Pull out the inner container from the outer container with the handle and forcefully throw it in free airspace. Release the handle! When landing with modern rescue equipment in the correct weight range, the pilot can expect to remain unharmed. After an uninjured landing with the reserve parachute, signal possible observers that you are fine, for example by packing up the equipment. Also inform the mountain rescue and police to prevent an unnecessary rescue operation.

> The European emergency number is 112. The „Alpine distress signal“ consists of 6 optical or acoustic signals per minute (every 10 seconds) followed by a one minute break.

If the reserve gets caught in the suspension lines of the glider, try pulling the bridle of the rescue-system forcefully.

When you are the first person to help a pilot who was involved in an accident, the following observations must be made: Is the pilot responsive? Breathing okay? Pulse okay? Is there a bleeding that needs to be stopped? If the pilot is unconscious and has no apparent injuries, place him in the recovery position and check pulse and breathing constantly.

> If you experience a critical situation when flying, it is important to analyze the causes for that situation afterwards to understand your own mistakes in order to avoid them during future flights.

When a pilot complains about back pain after an accident or doesn't feel his legs anymore, suspect a spinal injury. He should not move, sit up or attempt to walk.

2.6 Human Performance

Before each flight the pilot has to decide whether he feels fit enough to fly safely and comfortably. Even a cold reduces the performance significantly and may cause difficulties with the pressure equalization in the middle ear. In strong thermals climb rates of 5 m/s or higher and height differences of up to 1000 metres can be achieved. When the pressure equalization in the middle ear is not possible during rapid changes in air pressure, severe pain and dizziness may occur.

Figure 30: Well prepared for the altitude - Andreas Schubert and Alex Füg during the Papillon expedition on Mount Everest in 2011

Figure 29: Papillon expedition in 2011 to the Mount Everest. From an altitude of about 3500 metres MSL, a pilot must anticipate the physical effects of the reduced oxygen partial pressure. Possible effects are a deceptive wellbeing (euphoria), an impaired judgment, drowsiness, altered colour perception and a limited field of view. If a pilot notices first effects of oxygen deficiency he has to leave the thermal and begin a descent, possibly using a rapid descent method which does not burden the body (for example, big ears). • Photo: Daniel Müller, Pilot: Janis Stüberath

Figure 31: Landing beer at the end of a beautiful day during a Papillon paragliding trip. Never fly with residual alcohol in the blood! Also fatigue after a party on the evening before can lead to poor concentration and reduced performance. Don't fly until your full physical and mental capacity is reached again. • Photo: Moni Eller

Sometimes peer pressure tempts a pilot to fly against his own security concerns, because the individual does not dare to express those concerns in the group. Also, the tendency to fly risky manoeuvres and to overestimate oneself is greatest when someone is observed by others and wants to be admired.

A daily fluid intake of approximately 4 litres is recommended of adults when exercising. Concentration and coordination disorders or circulatory problems may be a sign of dehydration.

Hypothermia slows down motor skills and responsiveness.

Note: Wind has a cooling effect on the temperature perception (called: wind chill effect). Example: At a speed of 35 km/h an air temperature of 0° C corresponds to the sensed temperature of about -15° C.

It is better to stand on the ground and wish you were flying than to fly and wish you would stand on safe ground.

Remember that the landing requires intense concentration. Land before your mental and physical performance decreases.

Figure 32: Swarm of sea birds at the southern Spanish Atlantic coast in Matalascañas. • Photo: Hauke Scholz / FLY-ALGODONALES.COM

2.7 Nature and Environmental Protection

Paragliding is a sport in nature and therefore requires the pilots exercise discipline and caution in order to avoid conflict with the interests of farmers and the protection of the environment.

It goes without saying that the flora and fauna should be protected as much as possible. Do not litter. Don't cause unnecessary noise.

Livestock and wildlife shy away from noise and need special consideration in winter, spring and early summer.

If we force animals to flee in winter, it is very energy-sapping for them in the snow.

Birds breed in spring and early summer. Flights near breeding raptors should be avoided. With a display flight an eagle tries to guard his territory. If you observe such a behaviour, change your course and leave the area as quickly as possible.

If you fly in midsummer several hundred metres above the launching field and find a bird of prey in the same updraft, you can continue to fly normally, but should refrain from sudden manoeuvres.

Do not fly over wildlife with a distance of less than 150 metres. When possible, change your course to circumnavigate animals widely.

Reactions of wildlife to paragliders depend on the regularity of over-flights (habituation), the terrain structure (wells, ditches, etc.) and the vegetation, because trees and shrubs can provide shelter.

Figure 33: Edelweiss found along the wayside, discovered during a Hike & Fly tour. Photo: Felix Wölk

3 Meteorology

Figure 1: Castellanus clouds are towering clouds that can continue to grow to cumulonimbus clouds and therefore are a harbinger of a storm. Very dangerous. If the clouds grow as big as in the picture, land immediately!

Paragliding is the easiest and most importantly the safest way to fly. However, the precise assessment of suitable weather conditions is required for safe flights and can be quite challenging.

After a summary of the most important physical parameters, remarks on air circulation and the dangers of storms, thermals, föhn and valley winds follow. Where are the boundaries between long hours of safe flying and life-threatening weather developments?

At the beginning of your flying career your flight instructor decides on the flight operations. In the approximately 14-day training for the A-licence student pilots already learn a lot about the weather and its possible dangers. Later, thermal flying courses and guided holiday trips offer beginners the opportunity to fly in selected flight areas around the world under expert supervision.

Figure 2: Aging anticyclone. The air pressure at high altitude is decreasing. The wind increases before the cyclone.

Detecting dangerous weather situations is extremely important for the safety of aviation sports. Weather information can be obtained from different weather reports and services on the Internet. Some flying sites feature weather cameras that provide useful additional information about current weather conditions. Shown wind values may differ from the actual wind though.

3.1 Physical Parameters

3.1.1 The Troposphere

The layer of air around the Earth is called atmosphere. However, weather only takes place in the lowest layer of the atmosphere, the troposphere. In our latitudes it reaches 8-12 kilometres high, depending on the season. The troposphere is characterized by an average temperature decrease with height of 0.65 ° C/100 m.

Upwardly it is limited by the tropopause, a weather-effective barrier. There temperatures between -50 ° C and -60 ° C prevail (in our latitudes), where it no longer gets colder with increasing altitude.

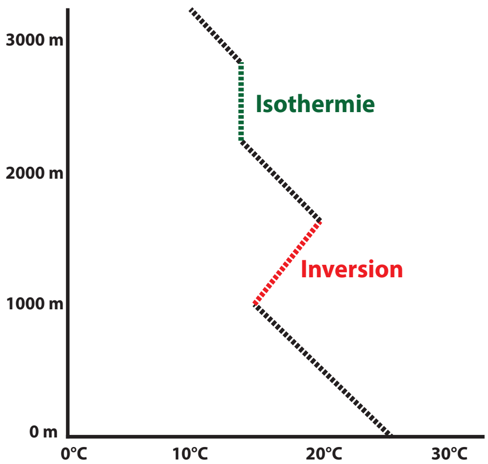


Figure 4: Temperature emagram

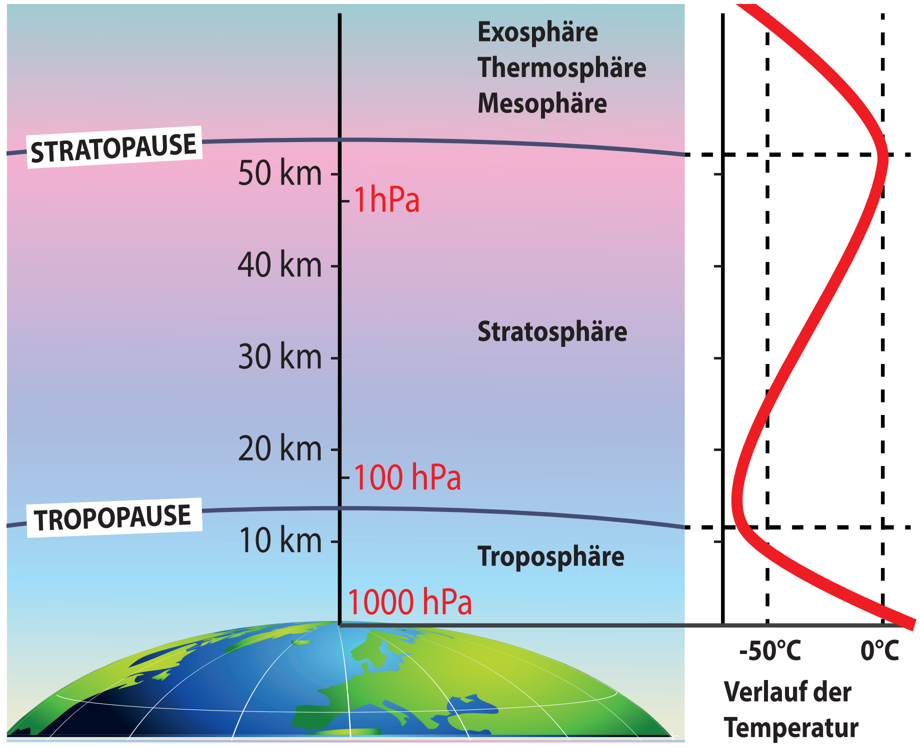


Figure 3: Our Atmosphere

The tropopause can be thought of as a saucepan lid, under which the „ups and downs" of warm and cold air with cloud formations and dissipations take place.

3.1.2 Temperature

However, the daily weather conditions usually do not show a homogeneous temperature profile. If the temperature remains the same with increasing altitude, it is called isothermal and when it increases, an inversion is present. The change of temperature with the altitude is referred to as temperature gradient (Fig. 4).

In the centre of high pressure areas the temperature inversion layer often reaches to the ground. A ground inversion can also occur overnight, when the ground - and thus also the overlying layer of air – cool off through radiation.

In the sinking air masses of high-pressure areas there is a compression with heating.

3.1.3 Air Pressure

The atmosphere is subject to the force of gravity. By the weight of the atmosphere pressure on the surface of the earth is applied, the air pressure. The lowest layers of air are most compressed, because they are pressed together by the weight of the overlying air masses.

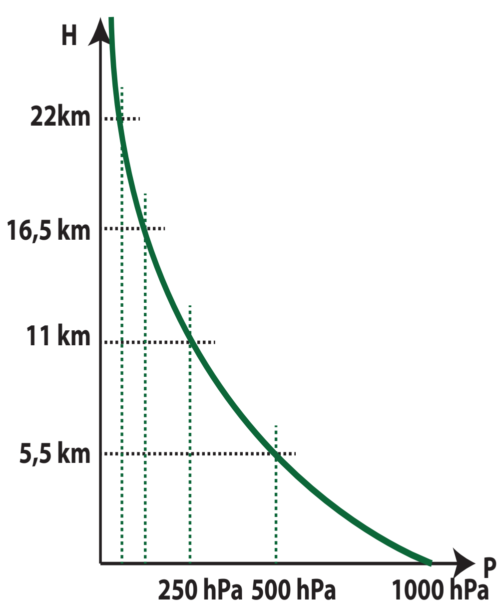


Figure 5: Decrease in air pressure with altitude

Figure 5 shows that the air pressure is highest at the surface and then decreases logarithmically with altitude. This reduction in air pressure is used in variometers to indicate the climb or sink rate and the altitude. The average air pressure at sea level is 1013.25 hPa. Simplifying, one can say that it is halved with every 5500 metres.

Rule of thumb: Air pressure decreases by about 10 percent every thousand metres.

For the pilot, it is important to know that without acclimatization at altitudes above 3,000 metres the perception and ability to act are already impaired. Therefore untrained pilots should not fly in thermals at that altitude for too long.

3.1.4 Air Density

The air density is the ratio of the number of air particles and their mass to a volume. In the so called standard atmosphere a cubic metre of air weighs 1225 kg. The volume of air increases with altitude due to the decrease in pressure. Cold air is denser due to lower molecular motion and thus heavier than warm air. Due to its higher temperature (and therefore lower weight) than the colder ambient air, warm air rises as thermals.

The air density is also dependent on the humidity: Water gas is lighter than the other gases of the air mixture. Due to its lower density, moist air is lighter than dry air and therefore rises. If it were different, there would, for example, be no clouds, but only fog.

Paragliding is easy. Student pilots glide down the training slope during the first day of their paragliding course already. However, the independent judgement of meteorological conditions in the Alps before first solo flights there is more difficult.

Therefore we recommend:

1. Regular browsing on weather pages
2. Reading weather books
3. Attending a Meteo-seminar

3.1.5 Humidity

Within the troposphere there are varying amounts of gaseous water in the air. The maximum quantity of water gas, which may be in the air depends on the temperature of the air.

The higher the air temperature, the more water gas the air can absorb. The gaseous water in the air is measured in grams per cubic metre and is called absolute humidity.

The relative humidity expresses the degree of saturation of the air in percent. It is the ratio of the actual absolute humidity to the maximum possible humidity:

$$\textit{relative humidity} = \frac{\textit{absolute humidity}}{\textit{maximum possible humidity}} \times 100$$

Figure 6: Visible humidity at the “Fliegerdenkmal Wasserkuppe” • Photo: Lisa Gast

If the absolute humidity in the air is the same as the air can maximally hold at the existing temperature, the relative humidity is 100%, the air is saturated. On the ground, humidity averages 60-80%.

The temperature at which saturation is achieved is called dew point. The difference between the currently existing temperature and the dew point indicates how close the air is to being saturated. This value is called (dew point) spread.

Unsaturated air reaches its dew point by cooling, for example through a thermal updraft, or moisture accumulation.

Digression: Considerations regarding Climate Change

Global warming increasingly influences these circulations:

There are concerns that the Gulf Stream weakens due to the enormous freshwater entry into the North Atlantic and possibly even stops in a few years.

Measurements of the compensatory currents in the depths of the North Atlantic Ocean have shown that the current has already weakened by more than 30%. A collapse of the Gulf Stream would cause cold and dry winters and hot summers with sometimes long-lasting droughts in Central and Northern Europe.

The current global warming since the 1970s is responsible for the greatest extinction of species in Earth's history. Animals and plants can neither adapt, nor seek new habitats. Only an immediate drastic reduction in CO2 emissions can counteract climate change.

Paragliding is a modern environmentally friendly flight sports without engine noise or CO2 emissions.

Our flight school buses run on biodiesel since 2007. The Flight Center Wasserkuppe is a wooden building made of domestic timber.

Climate change also impacts aviation: More flight days, warmer weather, better thermals. Increasing threats are more frequent and more violent overdevelopments and devastating storms.

Then more water gas is present in the air than it can hold. The excess moisture condenses and forms a cloud. The condensation level is reached.

Condensation cores are particles suspended in the air, like smoke, salt or plant pollens, where water droplets settle to form visible clouds or fog.

At high temperatures the air contains up to 4% water gas. The percentage of the other gases is reduced to 20% oxygen and 75% nitrogen (instead of 21% and 78%).

As a measuring instrument for determining the relative humidity, the hygrometer is used. The water gas is released into the air through evaporation. Evaporation takes place at any temperature.

During evaporation, the energy required for this process is taken in form of heat from the vicinity of the evaporating water. Evaporation thus has a cooling effect. The energy is not lost, it is released again during condensation.

Figure 7: A beautiful day in the Alps: ridge soaring above the Seceda, in the background the Sellastock. • Photo: Andreas Schubert

Condensation releases heat that is emitted to the environment.

This phenomenon causes - in addition to the exchange of warm and cold air - for a large-scale heat transport as 3/4 of the earth's surface is covered by water.

Through solar heat huge amounts of water are evaporated. With the large circulation flows of the earth, water gas and the contained heat are transported and released again later through condensation.

3.2 Thermodynamics

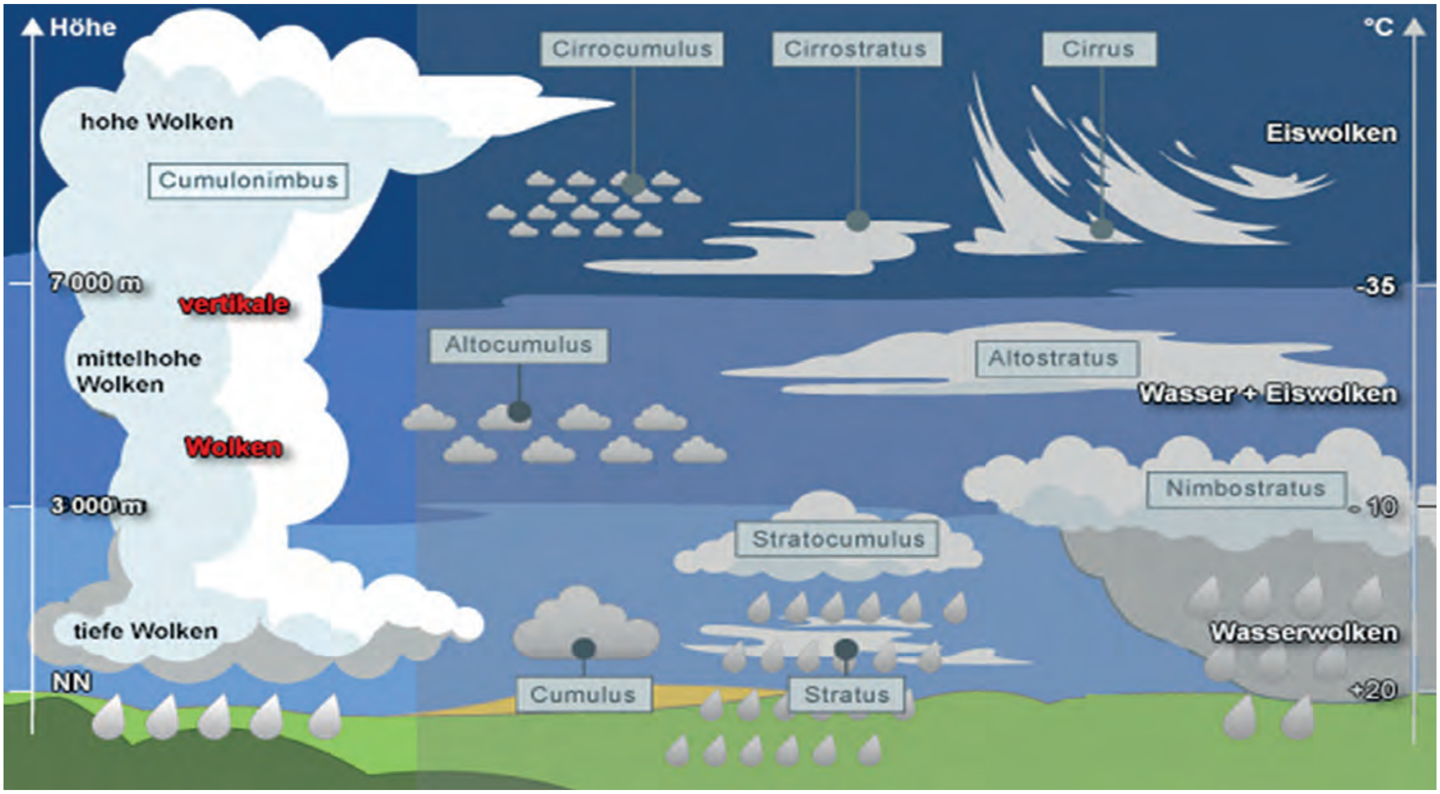


Figure 8: Cloud layers and types • Courtesy of www.wetteronline.de

A dry air mass with a temperature of 5° C above the ambient air expands due to the reduction of air pressure as altitude increases.

This expansion causes a decrease in temperature by 1° C per 100 metres. This change in temperature is called dry adiabatic lapse rate, when the heat exchange of the ascending air with the ambient air is neglected.

Similarly a compression causes heating at the same temperature gradient, whereby the effect of foehn and the subsidence inversion in high pressure areas can be explained.

The relative humidity of an ascending air parcel increases with increasing altitude owing to the decrease in temperature until it reaches 100 percent. The dew point (the condensation level) is reached and the water gas contained in the air condenses.

The heat released through condensation partially compensates for the cooling of the rising air. Therefore the temperature doesn't decrease 1° C per 100 metres anymore, but only 0.6 ° C. This new temperature gradient is called moist adiabatic lapse rate.

The ascent of air masses is not complete until there is no more temperature difference between the air mass and the ambient air.

In the worst case that scenario could happen to a pilot in a thunderstorm, whose updrafts may only be stopped by the tropopause.

Cloud classification:
1) below 3000m: low clouds
2) 3000m - 7000m: middle clouds (alto)
3) above 7000m: high clouds (cirrus)

Stratus = low-level cloud with horizontal layering, uniform base
Cumulus = heap or fleecy clouds
Nimbostratus = cloud with great vertical development

Fleecy clouds after nice weather indicate imminent weather deterioration. In bad weather they indicate weather improvement.

Figure 9: Left in the picture there is a strong cumulus cloud; in the centre an overdevelopment with its characteristic anvil shape. There are strong vertical air movements. Do not fly! • Photo: Marc Niedermeier

3.3 Thunderstorms

The rising air masses remain warmer than the ambient air in spite of constant cooling. The atmosphere is unstable.

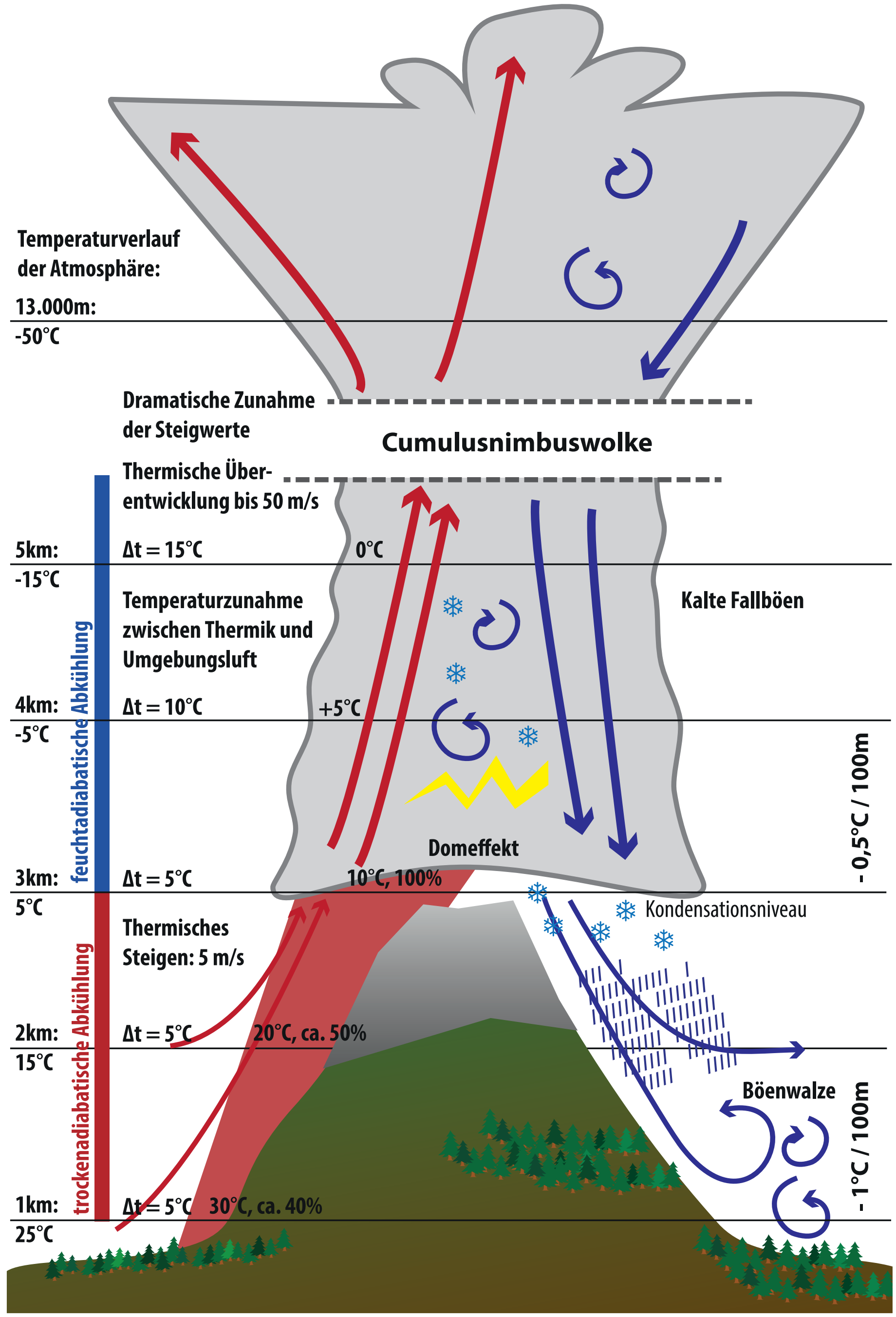


Figure 10: Schematic representation of an overdevelopment

Cold air at higher altitudes favours thunderstorm development because the temperature difference between the rising air in the cloud and the ambient air is even greater. The vertical wind speeds increase. Cumulus clouds may turn into voluminous towering cumulus clouds with a cauliflower appearance within minutes and can continue to grow to kilometre-high cumulonimbus clouds (Cb) (thunderstorm clouds, precipitation). Dome effect: In the centre of the updraft zone the condensation level is reached later.

Not every rising warm air ends with a thunderstorm. High pressure will reduce the likelihood of a thunderstorm.

3.4 Wind

Wind is moving air and is caused by barometric pressure differences.

The wind direction is often given in degrees: 0° corresponds to North, 90° to East, 180° to South and 270° to West.

In the lowland the wind direction and strength near the ground can be seen roughly by the movement of cumulus clouds. In the mountains this is not possible, since local wind systems, such as valley winds or Venturi effects, determine the wind in the lower layers.

A distinction is made between dynamic, large-scale national and local, for example thermal, winds.

For a paraglider pilot an understanding of locally occurring winds is meaningful, because without a motor he relies solely on thermals or slope lifts.

The emergence of typical weather conditions is presented in a simplified form here.

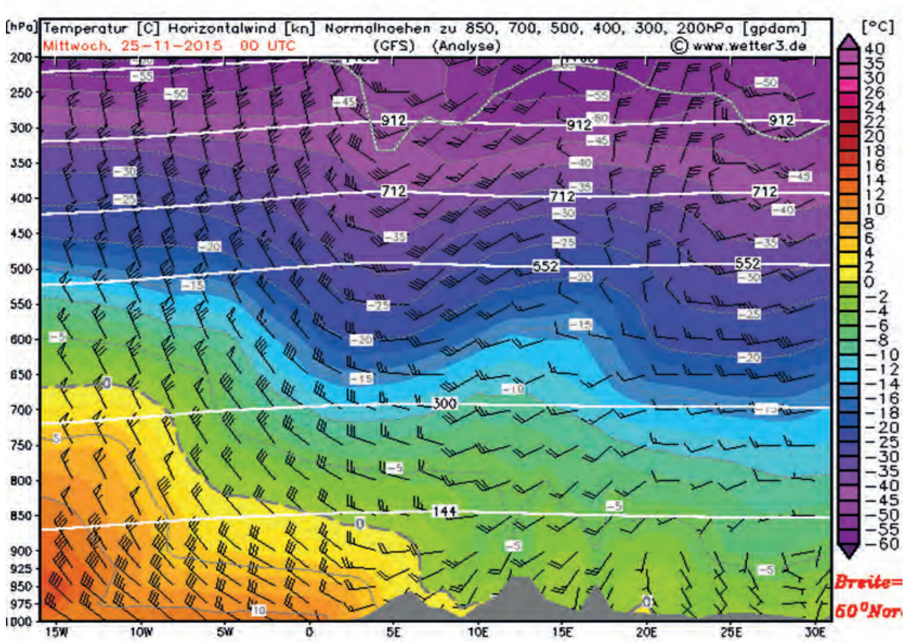


Figure 11: Wind forecast map for various hPa pressure surfaces - The arrows indicate the wind direction. The tip of the arrow indicates the direction in which the wind blows. Half a line at the rear end represents 5 knots, a full line 10 knots and a triangle 50 knots. • Illustration: wetter3.de

3.4.1 Circulation in the Northern Hemisphere - Dynamic Winds

Different angles of incidence of the sun, degrees of cloud cover, different orographic conditions and various other factors lead to different degrees of heating of air masses. Temperature changes affect air density and air pressure. Zones with different air pressures develop: high and low pressure areas.

Between the resulting pressure gradients compensation flows from high to low pressure areas arise. Winds are caused, which are named according to the direction from which they blow.

A downpour is a heavy, local and temporary rainfall, possibly with hail. In the upper area of a thundercloud an anvil forms.

Surrounding air which is not part of the thermal is also absorbed by the extreme suction effect. Speeds in the updraft can be as high as 50 m/s.

Another danger is the gust front (also called outflow boundary), which precedes a mature thunderstorm. Even kilometres away pilots are in danger. Therefore: No flights in the vicinity of thunderstorms!

Due to its higher pressure the outflowing cold air from higher altitudes slides under the warm air parcel near the ground, which then rises and feeds the thundercloud with new warm air. The result is an extremely turbulent gust front.

Days with a tendency to thunderstorms may still be "usable" in the morning. However, once thermal clouds develop over the launch site and begin towering (Castellanus clouds), you must land immediately.

A thunderstorm can form at any time of the day when cold air masses reach high. 9 out of 10 flashes equalize the load differences between updrafts and downdrafts. Only every 10th lightning reaches the ground.

These characteristics of different wind speeds should be memorised:

15 - 20 km/h: windsock swings in a stretched hanging position

20 - 25 km/hour: thin branches and twigs move with audible noise

30 km/h: whitecaps form on a lake

35 km/h: flags can be heard clearly (rattle)

On a glacier downdrafts can be expected on days with low winds.

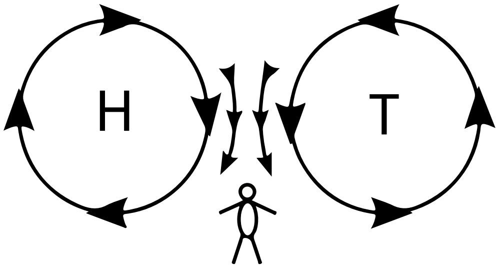


Figure 12: Buys Ballot's Law. „BuysBallot en" of Mormegil - Own work. Licensed under CC BY-SA 3.0 via Wikimedia Commons

The slower the air flows, the smaller the influence of the Coriolis effect. At ground level, the influence of the Coriolis force is less than at higher altitudes because the wind speed is low due to ground friction.

There is ground-level pressure equalization from high to low pressure areas, where the wind blows around the high pressure area and towards the lower pressure.

Mountains influence national wind systems and cause local wind phenomena.

Lines of equal pressure are called isobars and are shown in most weather charts. These provide information on the wind direction and strength and high or low pressure influence. The further the isobars are apart from each other, the weaker the wind.

The Earth's rotation causes an effect that deflects the wind in the northern hemisphere to the right and in the southern hemisphere to the left. It is called the Coriolis force. The deflection is so strong at higher altitudes that the air around high pressure areas flows parallel to the isobars in a clockwise direction.

The air flowing into a low pressure area is also deflected to the right, so that the flow around a low pressure area is counterclockwise. Close to the ground the Coriolis force is significantly lower due to friction, with a difference between land and sea areas. Overland friction is stronger than over the sea.

3.4.1.1 Low Pressure

The air mass convergence at the centre of a low pressure area causes a large-scale uplift of air. Through cooling, condensation and precipitation occur. Boundaries of different air masses are called fronts.

In a warm front warmer air pushed against colder air. Because of the lower density of the warm air it slides onto the cold air. During this lifting condensation occurs and a broad area of precipitation is formed.

First signs of a warm front are noticeable several hundred kilometres ahead of it. In weather charts it is marked with (red) semicircles on the front line. For paraglider pilots warm and cold fronts are equally dangerous in the summer months.

In a cold front heavy, cold air slides under warm air and lifts it, which causes adiabatic cooling with cumulus-type cloud formation, often kilometre-high frontal thunderstorms, Cbs and dangerous squall lines.

Even the moving cold air mass ahead of the front is dangerous already, because it spreads along the ground and through the valleys over long distances. Consequences of a cold front are large-scale, turbulent lift and a considerable wind increase.

High cirrus clouds may also be first signs of a cold front, which is why one can confuse them with a harmless warm front. In some cases a cold front may be preceded by altocumulus castellani (tower shaped clouds), altocumulus floccus (fleecy clouds) or overdevelopment. The front may also advance without any previous signs.

However, their forecasts in aviation weather reports are very reliable.

A cold front is marked with black or blue triangles in weather charts. When a cold front catches up with a preceding warm front due to its higher speed and both „mix", one speaks of an occlusion. These are depicted in weather charts with (pink) triangles and semicircles.

A weather improvement after a cold front or occlusion can only be expected when the cold air at higher altitudes (upper level trough) has also crossed an area. In Europe fronts occur both separately or as occlusions.

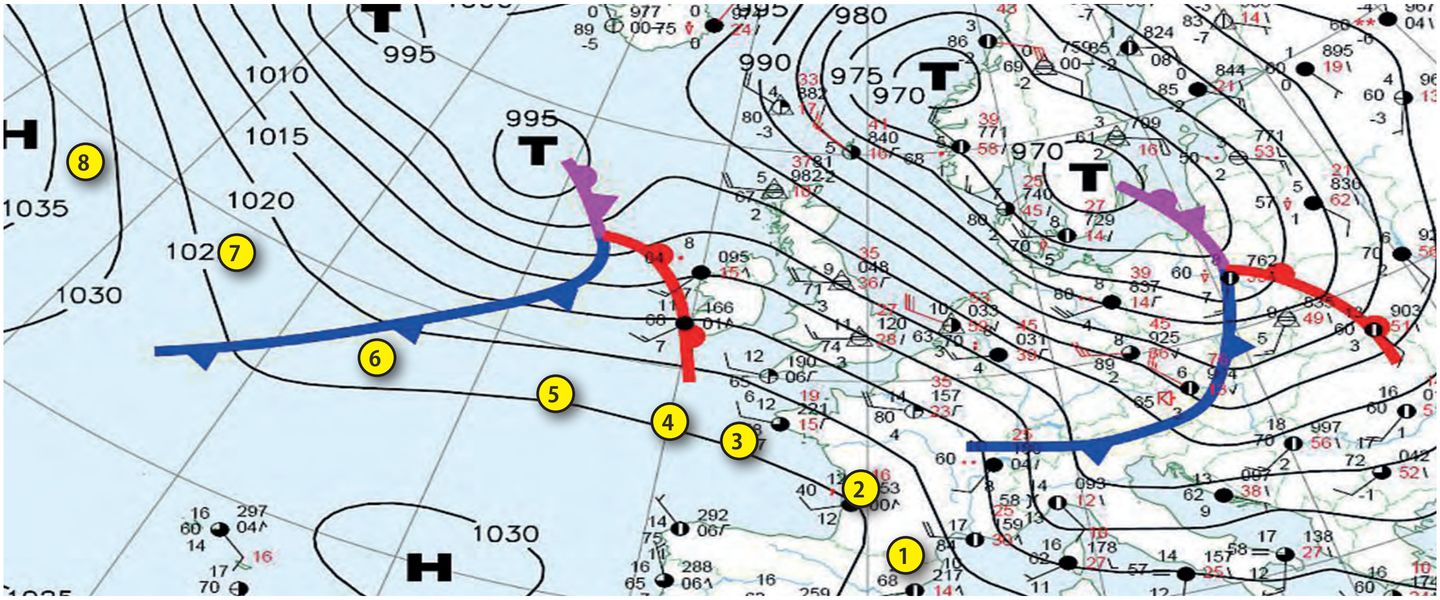


Figure 13: Weather Chart - Courtesy of the „Bundesamt für Meteorologie und Klimatologie MeteoSchweiz"

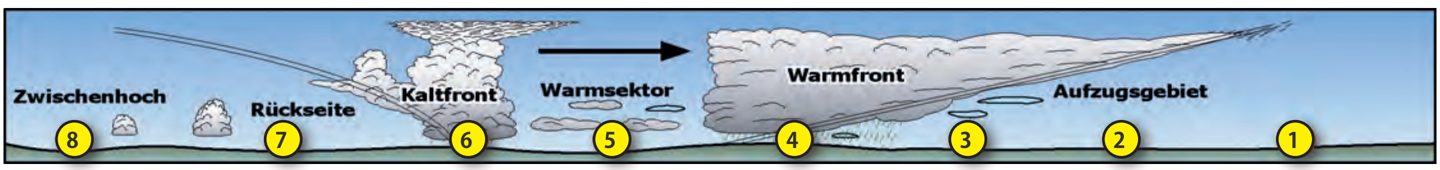


Figure 14: Ideal cyclone and front system. The figure shows that clouds first begin as "feathery" cirrus clouds (Ci), develop into Cirro- Cs and Altostratus As (stratus) and then condense until they become Nimbostratus Ns (rain cloud).

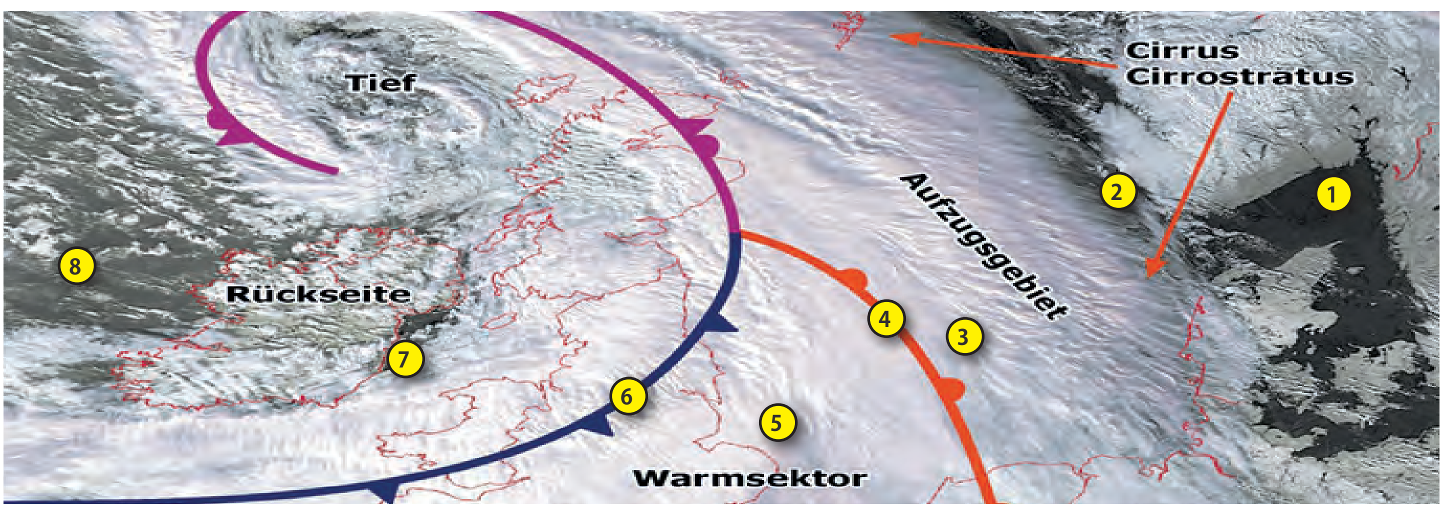


Figure 15: Satellite image with frontal system

3.4.1.2 High Pressure

In an anticyclone (high-pressure area) the air sinks over large areas and is thus heated by compression.

The sinking process in the high pressure centre reaches down to the ground and forms a subsidence inversion.

Above the temperature inversion layer the sunk, dry and heated air has dissolved the clouds and prevents new cloud formation. Nevertheless, individual cirrus clouds can still occur during the day at high altitudes.

At the end of high-pressure and changing meteorological conditions, flight conditions have to be assessed critically.

A relatively high pressure between two low pressure areas is called ridge of high pressure.

Below an inversion thermals may arise through unobstructed sunlight.

The rise of the thermals is limited by the inversion, since the temperature difference of the thermal and the ambient air decreases until the temperature and therefore pressure are finally equal.

The inversion is also referred to as a weather effective barrier. If the barrier is sufficiently high, cumulus clouds can form beneath the inversion.

When thermals develop without the formation of clouds, one speaks of blue thermals. Thermals in high pressure areas with light winds may be challenging for occasional pilots, but easily manageable by experienced pilots.

3.4.2 Thermals

A thermal updraft can weigh many hundred tons. When the thermal rises it follows the angle of the slope. Because of its inertia, the condensation level (cloud base) is often behind the launch site.

Figure 16: Thermal separation edges - The pilot can fly from one thermal updraft to the next and has – in this area – at least two sources for a successful thermal entry. With sufficient altitude he can begin circling in the first thermal source, close to the second (lower) thermal source he needs to fly “eights” away from the ridge. • Photo/Illustration: Papillon

Dry, sheltered ground surfaces (especially dry meadows and cornfields) heat up more than moist forest areas, where much of the solar energy is required for evaporation.

Heated ground heats the overlying layer of air. The thickness of this layer and the possibility to rise as a thermal depends mainly on the intensity of solar irradiation, the type of ground and the wind.

If an air mass warms up more than 2 ° C compared to the ambient air, the lift caused by the lower density of that air parcel is sufficient to penetrate the overlying colder air. The result is a thermal bubble. The thermal release is favoured by wind, which pushes the warm air parcel to an obstacle, until it eventually “tears off” and rises.

At such separation edges hot air rises frequently, resulting in pulsating thermals that can form a thermal “hose”. Those edges are, for example, ridgelines, bends in ridgelines, snow lines, forest edges, waters (water warms up more slowly than a land surface) or cloud shadows. In the mountains they are normally located above the region causing the warm air.

Depending on the temperature difference climb rates of up to 10 m/s are possible. In thermal overdevelopments (Cumulonimbus clouds) climb rates can be up to 50 m/s! The higher the temperature differences on the ground, the stronger a thermal.

Figure 17: Blue thermals in Algodonales
Photo: Norbert Fleisch

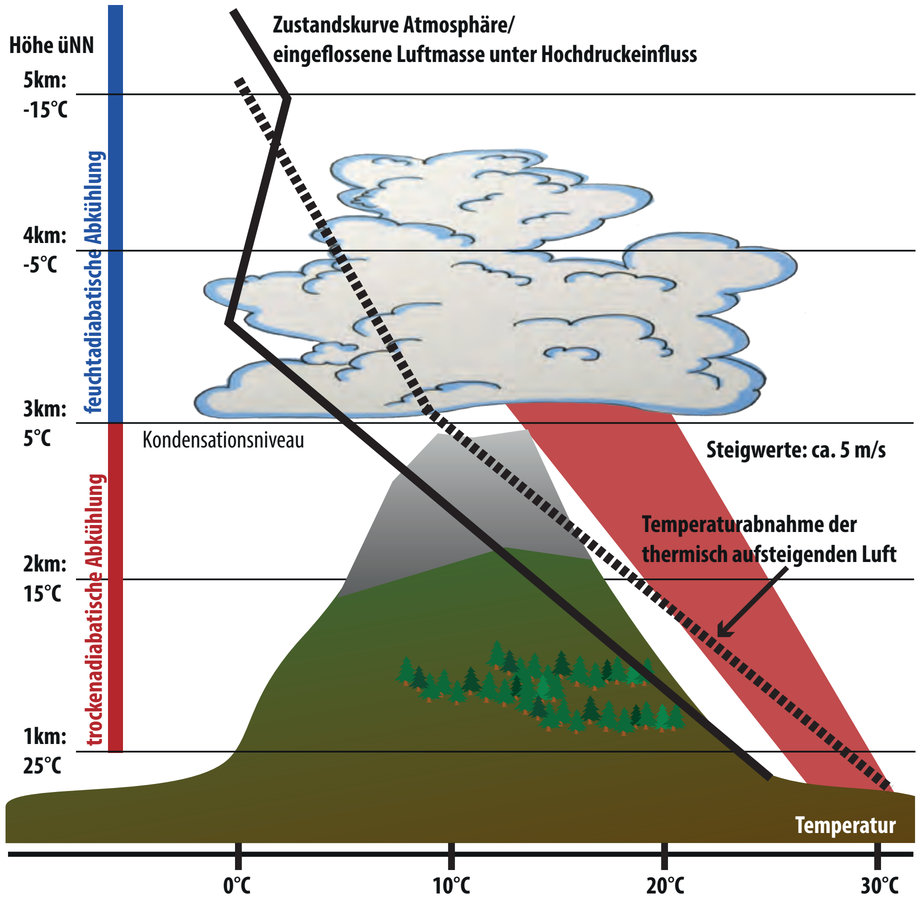


Figure 19: Emagram

Figure 18: En route in the central Dolomites.
Photo: Andreas Schubert

Paraglider pilots should leave a thermal at climb rates of more than 5 m/s and land.

Stronger thermals are only safe for experienced pilots, because the turbulences at the edge of the thermal would be strong too, which may cause problems with the paraglider.

The low sink rate of a paraglider is quickly compensated in thermals, so hour-long flights are possible. Inexperienced pilots should be careful with thermals.

Thermaling is best learned during special seminars. Occasional pilots who rather seek quiet gliding, should use the calmer morning and afternoon hours, when the thermals are not so strong.

Figure 19 shows a typical emagram (= diagram used to display the temperature lapse rate and moisture content profile in the atmosphere) for a high pressure area in summer. The dashed line shows a rising thermal with an originally 5 ° C higher temperature reaching the condensation level.

In 1500m the temperatures equalize in the inversion of the high-pressure area. The rise of the thermal will be terminated.

This stable weather offers good flying conditions below the inversion. You can see such inversions, when you stand on mountaintops. The air below the inversion is turbid due to higher humidity and pollution, while the air above is very clear.

How a thermal develops with altitude depends on the temperature profile or lapse rate. Depending on the temperature difference between a thermal and

Before a pilot begins a thermal flight, he should check the available landing spots in case he has to perform an unexpected outlanding. Expect local updrafts and downdrafts above the landing field. Abrupt changes in wind strength are possible.

Figure 20: Flight over Monaco • Photo: Moni Eller

Figure 21: Currently, the pilot is on the windward side in the updraft area. If the wind gets stronger, he must be careful not to be pushed into the leeside of the mountain as the updraft component weakens with increasing altitude while the horizontal wind speed increases. • Photo: Norbert Fleisch, at the XC seminar in Slovenia

the surrounding air, an air parcel rises slower or faster.

An example: If the temperature gradient of the ambient air is greater than the adiabatic lapse rate of the ascending air, an unstable stratification is present. Despite cooling by expansion, the temperature difference increases. The updrafts are getting stronger. Conditions become highly turbulent when updrafts abut an inversion layer.

Thermals can be distinguished in thermals forming clouds and blue thermals.

In cloud thermals the clouds shape gives visual clues about the centre, height, offset and phase of the updraft.

In blue thermals there are no overdevelopments or thunderstorms, no shading by clouds that can affect the thermals, nor can a pilot fly into a cloud.

3.4.3 Dynamic Slope (or Ridge) Lift

When airflow strikes a mountain, an updraft is formed on the windward side and a downdraft on the leeside of the mountain.

The paraglider pilot uses the updraft on the windward side to compensate for the sinking of the paraglider.

The nature of the updraft depends not only on the wind speed but also the terrain. The maximum altitude is gained in the dynamic area of lift before the ridge.

When ridge soaring one should pay attention to the terrain. Irregularities in the slope profile and obstacles may create turbulence. Downwind (leeside) of an obstacle they can be expected up to a distance of ten times the obstacle height. At notches, flat pieces, the lateral edges of the slope and in the summit area the pilot must expect a decrease of the updraft and a simultaneous increase of the horizontal wind. The launch, landing and ground handling therefore require a clean technique.

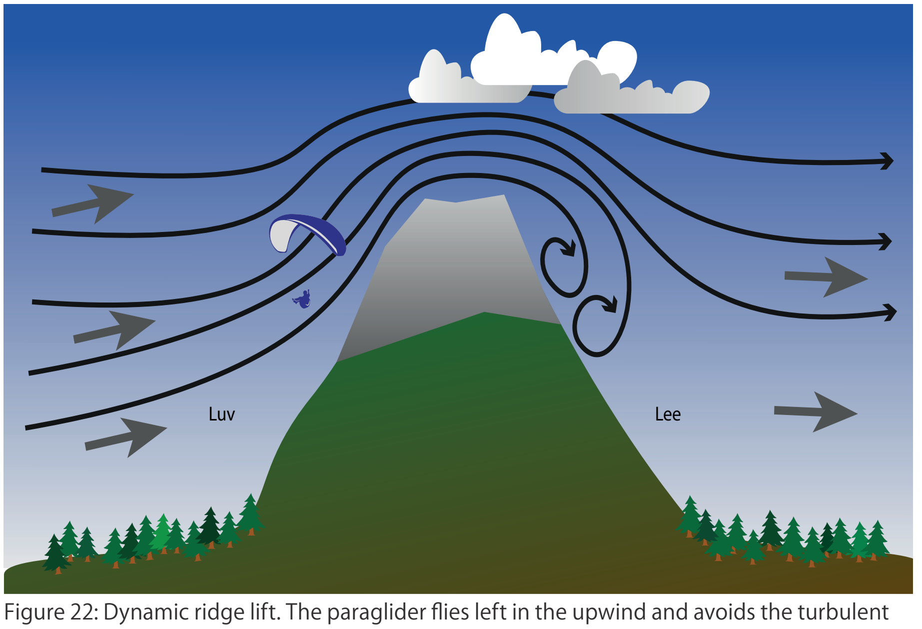


Figure 22: Dynamic ridge lift. The paraglider flies left in the upwind and avoids the turbulent area on the leeward side of the mountain (on the right).

The mountain should be in the free airflow and sufficiently wide so that the air doesn't flow around the mountain. Rugged edges and ridges can cause turbulences at the launch site. Over the crest of the ridge increased wind speeds prevail that can quickly push the glider to the leeside.

Thermals can form in the leeside of a mountain. They are usually stronger than thermals on the windward side. However, because of the dangerous turbulence they should be avoided. If you fly above a mountain in a windward thermal, which is pushed towards the leeside of the mountain, you should expect a high sink rate if you leave the thermal and make sure that you can still reach the windward side above the ridge.

Figure 23: Lenticularis (clearly defined lenticular clouds) occur in foehn conditions and are stationary - despite the strong wind - through constant new formation. Very dangerous! The pilot should not fly there! • Photo: Andreas Schubert

3.4.4 Foehn (Foehn Effect)

The foehn is a warm downwind in the Alps and a dangerous weather phenomenon for paragliders.

Flying is strictly prohibited in foehn conditions.

For example, between a low pressure area over the Bay of Biscay and a high pressure area over the Balkans humid air from the Mediterranean flows to the Alps. A south foehn develops. A foehn can occur with pressure differences of as little as 4 hPa between the north and south of the mountain range.

The air must ascend on the southern side of the Alps and cools initially with a dry adiabatic lapse rate (-1° C/100 m) to the condensation level and then with a moist (or saturated) adiabatic lapse rate (-0.6° C/100 m). The result is a foehn wall (cloud wall) with precipitation in the Southern Alps.

When the air starts to descend after flowing over the mountain ridge, the clouds dissolve because its moisture content is largely reduced after the rain on the windward side. The air is heated with a dry adiabatic lapse rate only, resulting in warming on the leeside, which is called foehn.

A local formation of cold air may lift the warmer and lighter (foehn) air. However, strong gusts can still brake through to the ground.

Frequently lenticular wave clouds (Lenticularis) occur. They arise above and behind the mountains, which cause vertical oscillations of the airflow. The oscillating air condenses when it cools down though the rise and evaporates again when it descends. The standing lenticular clouds at high altitudes cause the false impression of an absence of wind and rotor clouds may mimic thermal development above the valley or near the slopes.

Instead of lenticular clouds, torn Cumumli may also indicate a foehn. Sometimes there are no clouds present at all. So in order to recognize a foehn, the pilot must study the current weather condition (weather forecasts, foehn forecasts as a diagram, current wind values).

Valleys with longitudinal orientation to the wind have a high risk for rapidly developing strong foehn winds. But even in disconnected valleys shouldn't be flown, even when everything is calm.

The risk of sudden strong wind is too big. Thermal development on the leeward side of the mountain increases the risk of foehn wind breakthrough. With the arrival of the precipitation area of the approaching trough of low pressure, the foehn usually stops.

When a pilot notices from a great height, that the increasingly strong gusts of a cold surge hit the valley, he has to expect two things: a) extreme turbulences when attempting to land in the valley and b) that the rising warm air causes large updraft areas. He should not fly into the valley, but make an emergency landing on a slope as soon as possible.

The dangers for the pilot are strong winds with speeds of 50 up to 200 km/h in the foehn storm and the turbulences formed between ridges, which sometimes become visible as rotor clouds.

Foehn is created ahead of every front. The larger the pressure differences across the Alps, the stronger the winds.

A foehn storm is caused by the Venturi effect around mountain crests, passes and valley incisions.

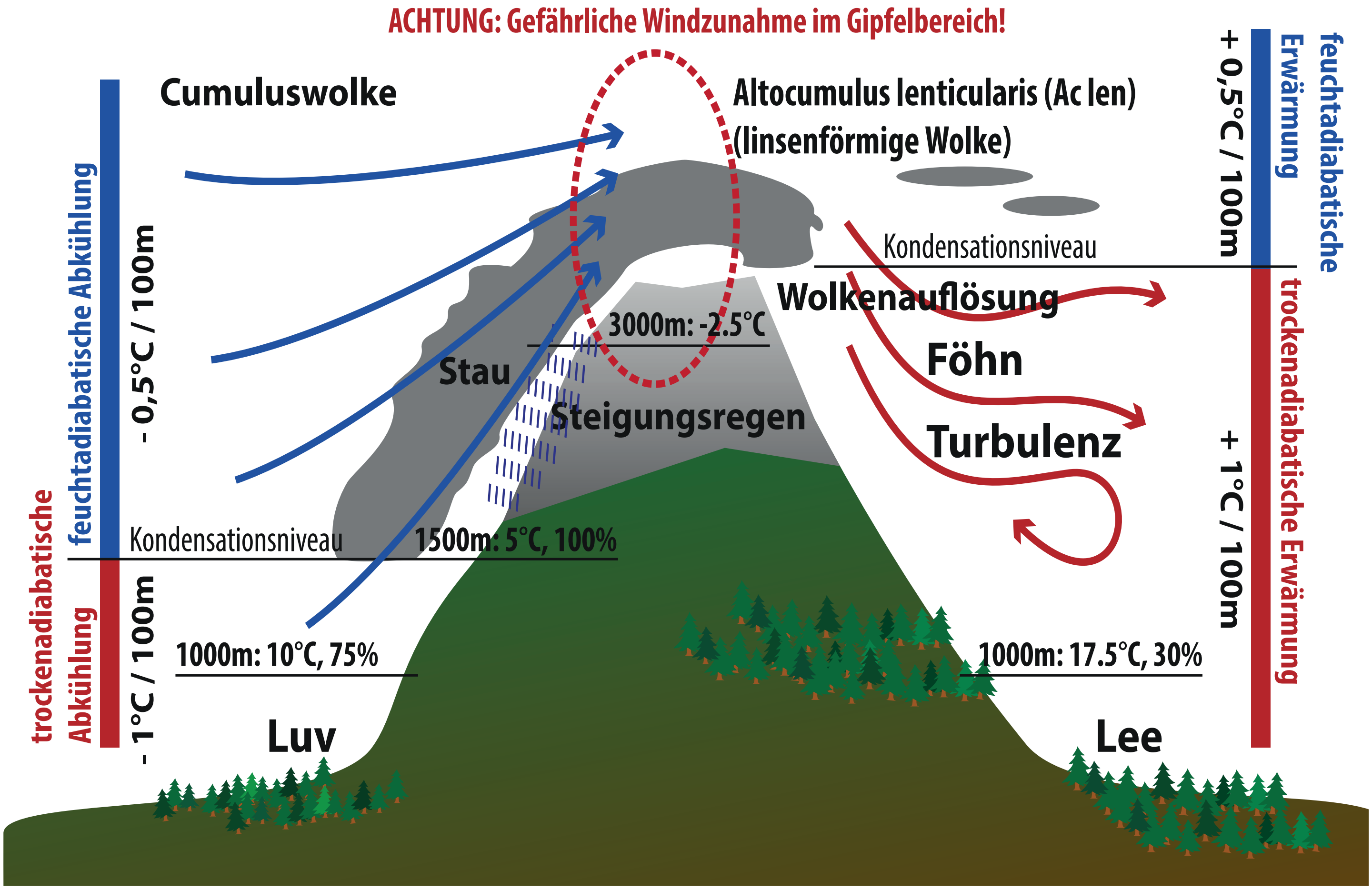


Figure 24: Foehn Effect

In addition to the south foehn there are other foehn winds. Wherever a spacious airflow strikes mountains, foehn effects are possible. They are called, for example, Mistral in France, Bise in Switzerland and Bora in Slovenia. In the Alps there are not only south foehn weather conditions, but also north foehn conditions.

No flights with a paraglider in foehn conditions!

3.4.5 Upslope and Downslope Winds

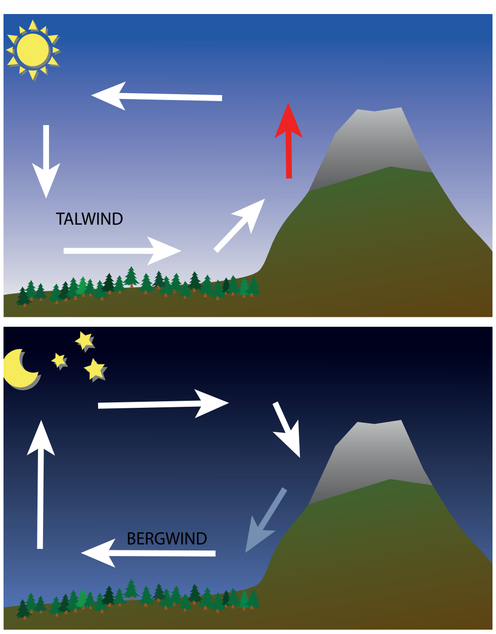


Figure 25: Mountain and valley wind

With sufficient sun exposure under the influence of high pressure in summer a typical wind circulation occurs in many mountain ranges. Valley winds (also called upslope or anabatic winds) usually blow on days with low winds at altitude. Wind speeds of more than 20 km/h at higher altitudes affect the valley wind: They replace it or exacerbate it dangerously.

When a strong valley wind prevails, it is particularly important that the terrain upwind of the landing site is free of obstructions. If the valley wind is so strong that the pilot flies backwards at trim speed, he has to fly active and highly concentrated, without or only slight use of the speed system and land without pulling the brakes.

The most famous valley wind in the European Alps is the „Ora" at Lake Garda, a strong wind on the northern shore between Torbole and Malcesine.

Air flows upwards on the slopes due to greater heating and draws colder air from the valley with it. When the slopes of a mountain range are heated in the late morning and the air rises in the mountains, air from the plains (or foothills) flows up from the valleys, which is called valley or upslope wind.

It blows between the valley and approximately 1500m GND and can exceed the airspeed of a paraglider. Only close to the ground the airspeed decreases significantly.

In the northern Alps hazardous lee turbulences have to be expected on southern slopes due to the northerly winds. Therefore pilots almost exclusively use northern slopes when ride soaring in the northern Alps. Northerly flying sites along the northern Alps offer excellent conditions for ridge soaring at high pressure weather conditions.

During the evening the slope surfaces cool down faster. The cold air flows down the slopes and causes a downslope (also called mountain or catabatic) wind. Now the warmer air over the valley rises, which is sometimes referred to as sunset thermals and often lasts until late at night.

Although legally flights at night are prohibited, physically, it is therefore possible to fly for hours in gentle sunset thermals. Through the extensively sinking air in the mountains a wind blows into the flatlands, which is the strongest in a starry night.

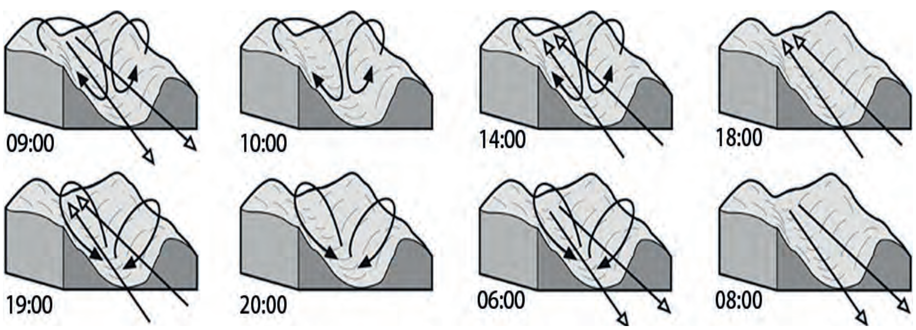


Figure 26: Mountain and valley wind system • © 2001 Oxford University Press, Heidelberg

Hazards: Valley wind can allow hours of flying above windward mountain ranges. On leeward slopes, however, they cause lee turbulences.

3.4.6 Wind Conditions in the Mountains

In mountainous areas it is difficult to predict exactly the wind conditions due to local wind systems. The actual wind usually differs from the predicted wind because valley wind systems, thermals and the blocking, channeling and deflecting effect of the mountains.

In some valleys up to three local winds from different directions converge. These form the so-called convergence zones. There are both stationary and migratory convergences. Above these areas updrafts are to be found. Near the ground however, the wind conditions are unpredictable.

In proximity to the ridge, the convergence of winds from different directions can cause severe turbulence.

In narrow mountain valleys the wind speed increases - the wind is channeled. This is called Venturi effect.

In the mountains the view is limited by the mountains. Owing to the local weather phenomena an approaching weather change is hard to detect.


Figure 27: Launch in Lüsem. • Photo: Felix Wölk


Figure 28: Launch site at the “Elfer” for a flight to Neustift • Photo: Viaframe

Author of the chapter: Air Law:

Anna-Lena Trabert, born in 1985 in Fulda, studied landscape architecture. After working in Augsburg, she moved back "home" and became a flight instructor.

„Why do I fly? Flying is like meditating. As a pilot you have to be focused at the present moment, the here and now. What was and what will be is pushed into the background; there is only you and the beautiful nature that surrounds you. For me it is the ultimate path to freedom and ease."

Figure 1: Pre-flight check completed, ready for takeoff. Always check the wind and weather conditions again immediately before takeoff.
Photo: Marc Niedermeier

Figure 2: Paraglider check at the "LTB Wasserkuppe" • Photo: Papillon

Figure 3: Unforgettable moments in the Alps, above Lüsen • Photos Felix Wölk

4 Air Law – Rules of Flight

As paragliding pilots we usually share the airspace with other pilots. It is therefore important to know where, when and under which conditions we are allowed to fly. The air (or aviation) law regulates and structures the manifold interests of all pilots.

Each country has specific laws and regulating authorities, which is why we only focus on the most important aspects here like right-of-way rules and only mention further regulations.

Other important topics to check for your country include: local authorities and their responsibilities, airspace, air traffic control, licence requirements and types of additional licences issued like tandem or paramotoring licences, equipment and insurance requirements.

4.1 The Licence

To get your paraglider licence, you typically need both a check-flight under the supervision of an examiner and sufficient theoretical knowledge about the topics discussed throughout this pilot handbook, demonstrated in a multiple-choice theory text.

Before the theory test and check-flight usually a specified number of theory lessons and practice flights are obligatory.

Figure 4: German A-license and IPPI-Card

For flights in other countries an IPPI Card is highly recommended in addition to your national licence.

It is an internationally recognized certificate issued by the World Air Sports Federation FAI, which provides a standard reference by which all national licences and rating programs may be compared. Therefore it serves as a proof of your flying experience, which you may need to show to those responsible for flight activities on a site like an instructor or flying site manager.

The ParaPro stage on the card reflects the pilot proficiency. For example, Level 4 corresponds to the restricted (A-Licence) and Level 5 the unrestricted (B-Licence) pilot's licences in Germany.

The IPPI Card is valid only together with a current national licence or rating card.

4.2 Equipment

In each country certain equipment is mandatory. Usually that includes: the (unaltered and certified) paraglider with a current 2-yearly check, a harness with a suitable protector, a reserve (for flights above 50 metres) that has been repacked recently, a helmet and often a rescue rope.

Pilots are also required to carry their licence, insurance certificate, identity card and possibly a logbook.

Pilots and holders of paragliders are responsible for the airworthiness of their "aircraft".

Obviously, the pilot must also be „airworthy" on every flight, which means fit to fly, not under the influence of alcohol, holding a current licence and insurance et cetera.

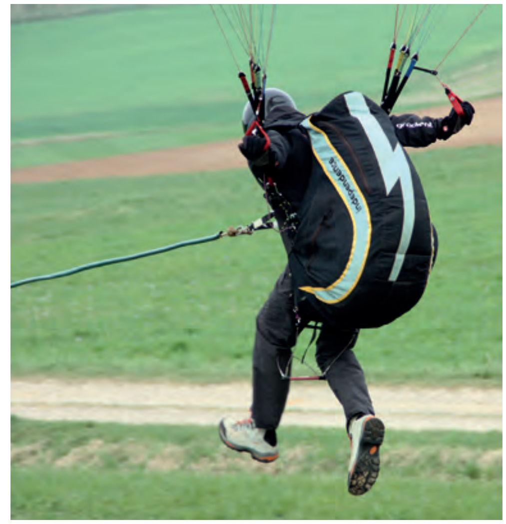


Figure 5: Winch-towing. If a pilot wants to launch at the winch, additional training at a flight school is mandatory.

4.3. General Rules

It is compulsory to perform a pre-flight check before each flight that has to include obtaining all information necessary and helpful for the safety of your fight, e.g. checking latest weather reports, the airspace you will be flying in and so on.

If a pilot needs to perform an out landing on an unintended field and causes some crop damage, the must report his name and address to the owner to arrange for a payment by his holder liability insurance or pay the damage immediately.

If the pilot makes an emergency landing and fails to inform the police or mountain rescue team, when he does not need their help, the cost of the search and rescue action must usually be paid in full by the pilot.

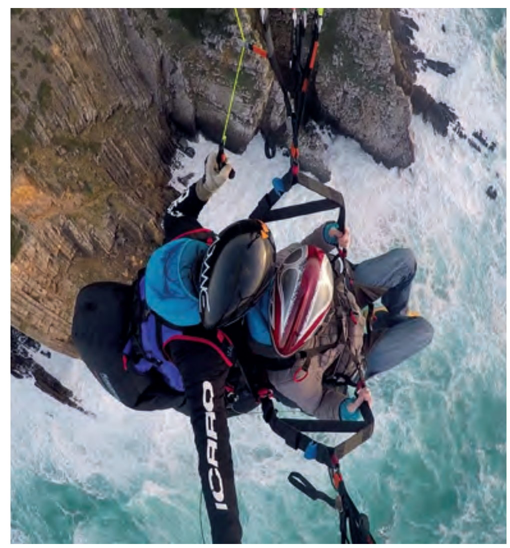


Figure 6: With an additional tandem licence passenger flights can be carried out.
Photo: Markus Fiedler

4.4 Right-of-Way Rules

4.4.1 General Traffic Rules

Since you are rarely flying alone in the air, there have to be right-of-way rules. Similar to driving, the principle of „right before left" is mostly accurate.

The most important general rule is "see and avoid".

We have to fly in a way that we never endanger ourselves or others and always check that our flight path is free before making any turns. A safe distance should always be kept in order to avoid dangerous close encounters.

Figure 7: After an additional training of about one week, pilots may also fly with a paramotor.
Photo: Simplify

> We have to fly in a way that we never endanger ourselves or others and always check that our flight path is free before making any turns.

Since different types of aircraft have a different level of manoeuvrability, there is a right-of-way hierarchy:

- Motor-powered aircraft, which are heavier than air, give way to:
  - airships, who give way to:
    - gliders, hang gliders and paragliders, who give way to:
      - balloons.

> Aircraft with a higher manoeuvrability usually give way to aircraft with a lesser manoeuvrability!

This means that more manoeuvrable aircraft give way to less manoeuvrable types of aircraft.

However, there are different rules regarding manoeuvrability and the right-of-way around the world.

> The right-of-way rules do not apply when a pilot is in distress or has lost its manoeuvrability, for example as a result of a line tangle. Such a pilot always has the right of way.

Always make sure you know the rules of the country in which you are flying.

For example, in the U.S. paragliders and hang gliders must yield right-of-way to all other aircraft (except powered ultralights) according to FAA Federal Aviation Regulations (Part 103)! So regardless of manoeuvrability, airplanes and helicopters, for example, have the right-of-way over paragliders there.

Figure 8: Crossing paths? The pilot coming from the right has the right of way! • Illustration: chrissicomics.de

> Usually correct: Right before left!

When two aircrafts are converging at the same altitude, the pilot on the right has the right of way. The pilot on the left has to give way, but can choose the direction he is diverting to.

Figure 9: Approaching head on with another paraglider, turn to the right. • Illustration: chrissicomics.de

When approaching head on with another paraglider, both pilots should turn to the right.

When overtaking another paraglider, pass to the right.

Figure 10: Overtaking another paraglider? Pass to the right. • Illustration: chrissicomics.de

When paragliding, always pay attention to hang gliders. They have a limited view of the sky above, fly at higher speeds and need significantly more time for an evasive manoeuvre than a paraglider.

Finally, there are rules for the last part of the flight, the landing, to ensure that everyone gets safely back on the ground.

Landing aircraft generally have the right of way over other traffic, because they only have a limited remaining altitude left to manoeuvre.

When several pilots are in a landing approach at the same time, the lower aircraft has the right of way.

4.4.2 Soaring and Thermaling Rules

On a slope: When two aircraft approach head on parallel to a ridge, the pilot with the ridge on his left side has to give way and escape to the right.

When two aircraft approach parallel to a ridge, an obstacle or in the updraft zone above a ridge, the pilot with the ridge on his left side has to give way.

The other pilot with the ridge on his right side cannot give way according to the rule that pilots approaching each other head on should both alter their course to the right.

When two pilots fly in an updraft above a ridge, the pilot with the leeward side of the mountain to his left has to give way.

Figure 11: Two-way traffic on the mountain? Mountain RIGHT has the RIGHT OF WAY, mountain LEFT must give way! • Illustration: chrissicomics.de

Again, this rule differs in different countries. For example in the U.S. the paraglider closest to the ridge has right of way when ridge soaring.

However, they also state that when approaching head, the pilot with the ridge to his right has the right-of-way.

Figure 12: Overtaking on the mountain is prohibited! • Illustration: chrissicomics.de

When using rapid descent methods like the spiral dive, the pilot performing the rapid descent must be sure he can exclude any risk of collision.

Figure 13: Circling at the same altitude? Keep a safe distance and always observe the other pilots carefully! • Illustration: chrissicomics.de

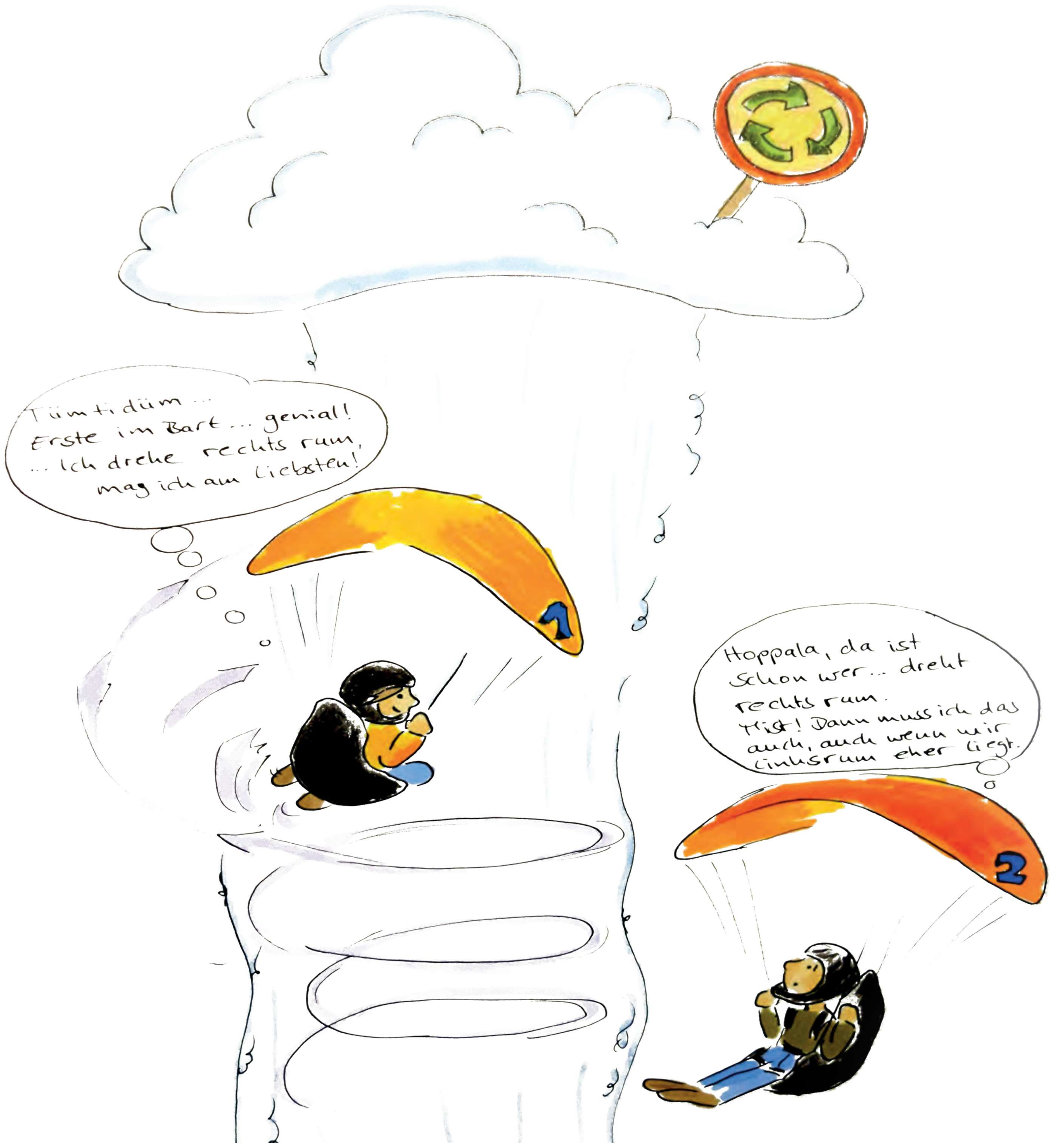


Figure 14: All pilots entering the same thermal have to circle in the same direction as the first pilot. • Illustration: chrissicomics.de

When thermaling, the first pilot to enter a thermal establishes the required turning direction.

☝ As long as the thermal is still within the ridge lift zone, ridge soaring rules apply.

Within a thermal the aircraft with the higher climb rate has the right of way over slower climbing aircraft.

Similarly, according to U.S. the lower glider has the right of way in a thermal, because it is more difficult to see the glider above then below.

Generally pilots who are already flying in a thermal have the right of way over other pilots who just approach the thermal.

4.5 Visibility and Cloud Clearance Requirements

Besides the right-of-way rules above, there are other regulations that govern when, where or how it is allowed to fly – or not.

Since paragliding always requires good visibility and we don't have equipment that would help other aircraft to locate our position, it is prohibited to fly at night.

Flights are only allowed from (30 minutes before) sunrise to (30 minutes after) sunset. In some countries the 30-minute extensions before sunrise and after sunset are subject to further rules, like displaying a blinking anti-collision light in the U.S. during that time.

You must constantly maintain visual reference with the surface. It is therefore forbidden to fly into clouds, as the orientation will be lost and we wouldn't be visible to others. Flights in or above stratus layers or fog are also prohibited.

It is also important to know, which distances to obstacles have to be kept. That again differs from country to country, but a safety distance of at least 50 metres to the following is generally a good idea:

- roads
- railway lines
- powered ski slopes
- lifts, cable and mountain railways
- people
- buildings

The minimum distance to highways should be at least 100 metres.

Flying underneath any lines (e.g. power lines) is prohibited.

4.6 Airspace Structure and Classification

To organize air traffic, the International Civil Aviation Organization (ICAO) has set an airspace structure with different airspace classes.

The various airspaces can be roughly distinguished in controlled and uncontrolled airspace. Only by introducing (tower) controlled airspaces, the separation of aircraft flying under instrument flight rules (IFR) is possible.

Different speed, visibility and cloud clearance requirements apply in each class of airspace. In regularly updated aviation maps, like the ICAO Charts or FAA Sectional Charts, airspaces and restriction areas are displayed.

4.6.1 Altitudes

Airspace classes have upper and lower limits. They are measured using the ground, the mean sea level or 1013 hPa as the reference datum.

As the actual pressure of the atmosphere varies with time and location, the

ICAO has established an international standard reference, the International Standard Atmosphere ISA.
At sea level the standard atmosphere is 1013,25 hectopascal (hPa)/millibars (mb) [or 29,92 inches of mercury ("Hg)] and 15 ° C [or 59 ° F].

The pressure altitude is the height above that theoretical level, where the pressure is 1013 hPa and important for assigning flight levels to airplanes.

4.6.2 Airspace Classification

While most countries use the classification system specified by the ICAO, there are still significant differences in how these classes are defined, where their boundaries are and which specific visibility and cloud clearance requirements apply.

Many countries don't use all of the ICAO airspaces. For exmple there is no class A and B airspace in Germany and only class C and G airspace in Sweden.

It is therefore very important to know the airspace you are flying in.

This is a general overview of the ICAO airspaces:

<u>Class A:</u> Controlled airspace. Flights under IFR (instrument flight rules) and with ATC (air traffic control) clearance only. All aircraft are separated from each other by ATC.

<u>Class B:</u> Controlled airspace around major airports. IFR and VFR (visual flight rules) flights, ATC clearance needed. All aircraft are separated from each other by ATC.

<u>Class C:</u> Controlled airspace around busy airports, but less busy than class B airports. IFR and VRF. Entry with ATC clearance or two-way radio communication. Separation provided for IFR/IFR and IFR/VFR; traffic information for VFR.

<u>Class D:</u> Controlled airspace around less busy, but tower controlled airports. IFR and VRF. Entry with ATC clearance or two-way radio communication. Separation provided for IFR/IFR; traffic information for VFR.

<u>Class E:</u> Still controlled airspace. Contract with ATC only required for IFR flights. Separation provided for IFR/IFR.

<u>Class F:</u> Uncontrolled. VFR and IFR.

<u>Class G:</u> The lower airspace, extending from the ground (GND). Class G airspace is uncontrolled. Therefore no contract with ATC is needed.

There are additional "special airspaces" - like prohibited areas, restricted areas or MOAs (military operation areas) – that also limit flights in certain areas.

For each airspace class different visibility and cloud clearance minima apply.

However, since they differ from country to country, no overview can be given here. Please check them for the country you are flying in!

Summed up, as paraglider pilots we spent almost all of our time in class G and E airspaces.

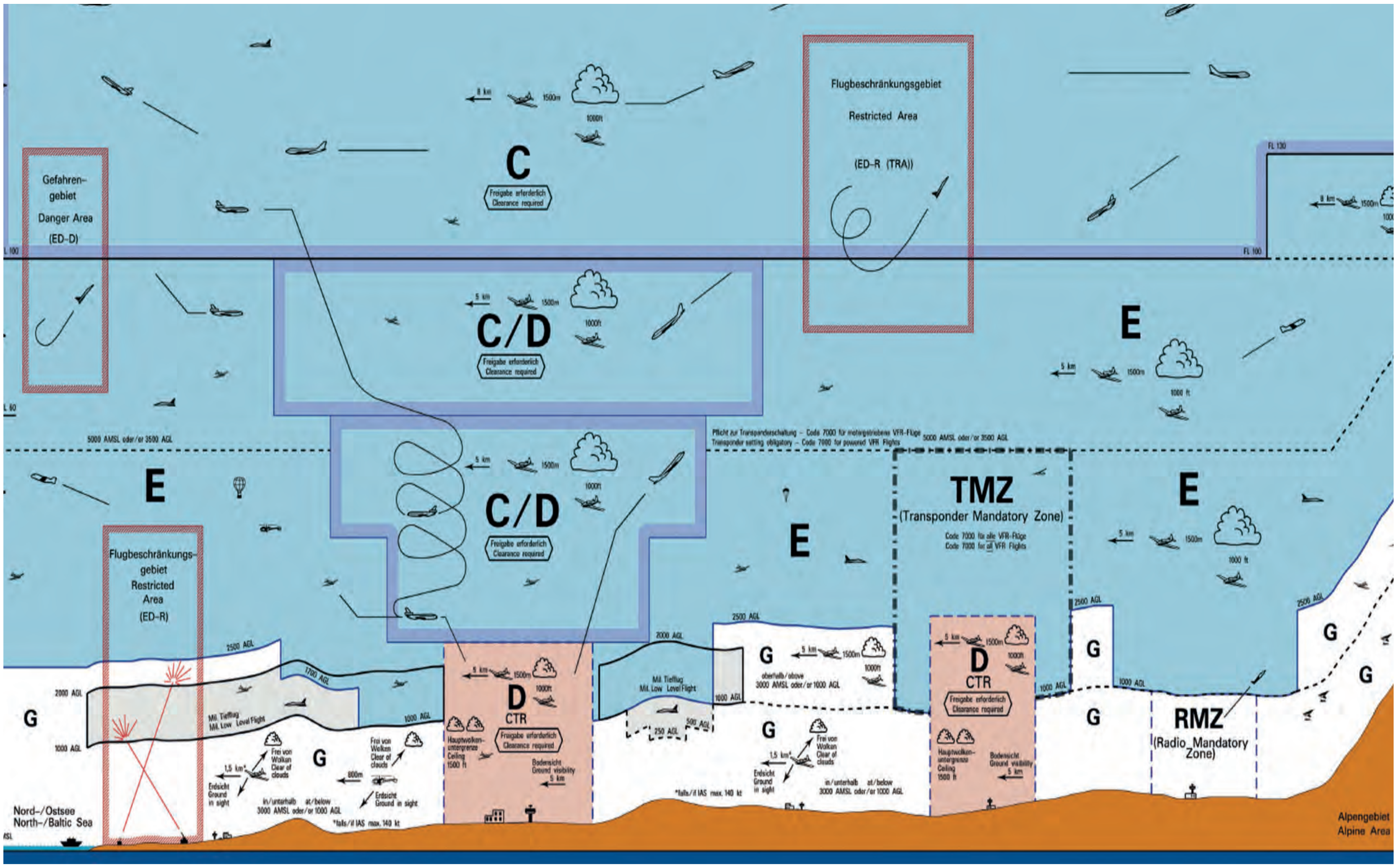


Figure 15: Airspace structure and classification in Germany • Courtsy of the DFS (Deutsche Flugsicherung GmbH)

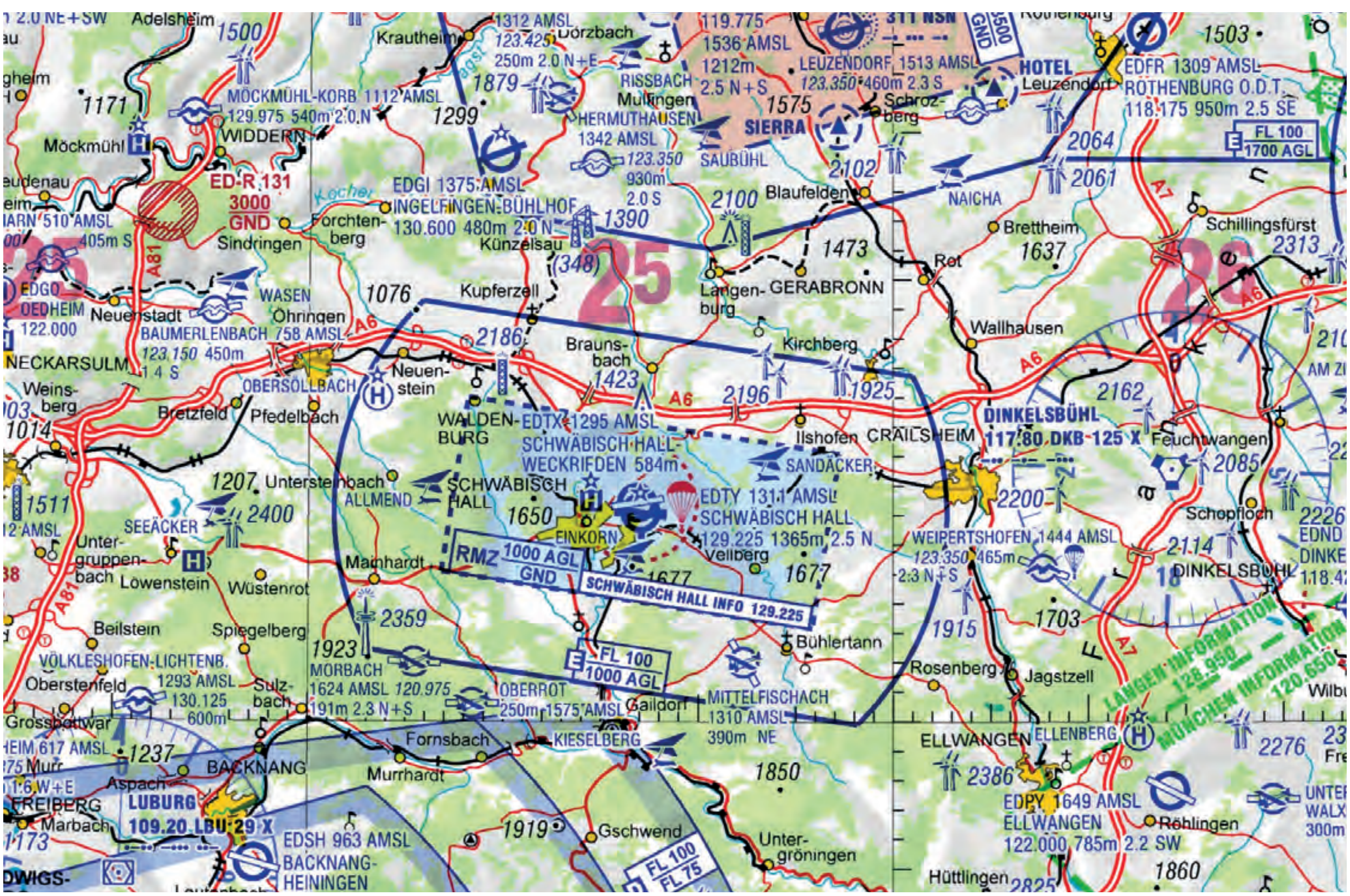
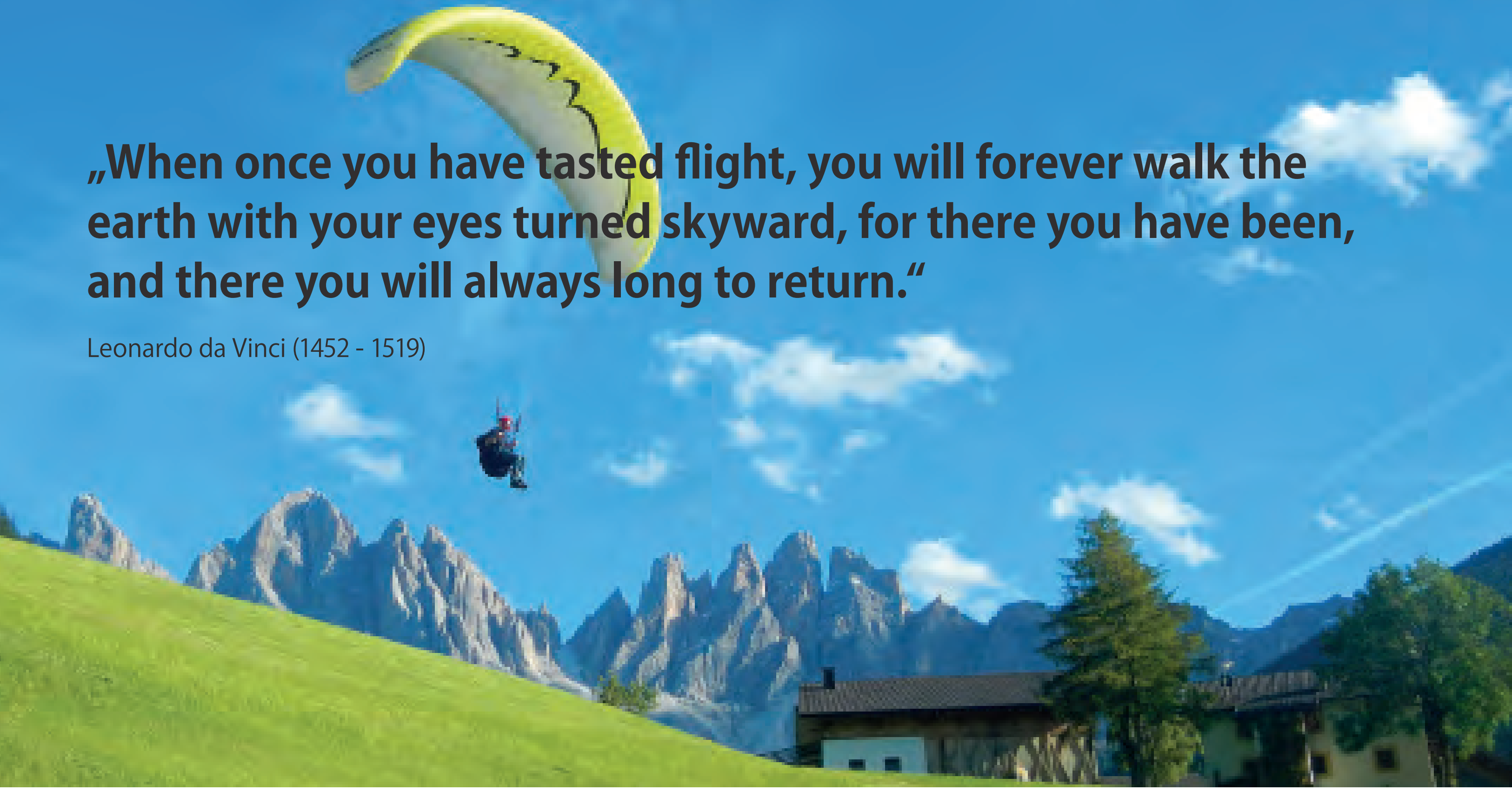


Figure 16: Section of the ICAO Aeronautical Chart 1: 500.000 • Courtsy of the DFS (Deutsche Flugsicherung GmbH). Not to be used for navigation!

„When once you have tasted flight, you will forever walk the earth with your eyes turned skyward, for there you have been, and there you will always long to return.“

Leonardo da Vinci (1452 - 1519)



When you become a paraglider pilot a whole series of breathtaking experiences lie ahead of you.

Your first gentle glide down a training hill... That already feels like a huge adventure.

Then your first high-altitude flight over forest and fields. Your first alpine flights in the second week of training. Against a backdrop of mountain peaks and valleys and at an altitude that will leave you speechless.

But it doesn't stop there. Only a few flights later you will see the launch site from above for the first time.

Thermaling, soaring along a coastline or long cross country flights.

The potential for moments of overwhelming joy and gratitude are endless.

Welcome to the world of paragliding!

Andreas Schubert
and the Papillon Team

Why flying makes people happy

„I feel the wind in my face, my feet dangling over mountains, valleys and the sea, lifted by the forces of nature only. The silence, no engine noise, no smell of petrol. Closer to the ancient human dream of flying than with any other aircraft.

The high-pitched beeps of my variometer confirm what I am feeling already: I am climbing. And with every further beep my elation amplifies. That's it! Suddenly I know why flying makes people so happy. It frees the mind. Right after takeoff any superfluous thought is gone. A shortcut to the here and now. Because it is something I do just for myself; something that serves no other purpose than to increase my joy.

No obligations, just me and the wind, the slope behind, the sea in front and the other lucky ones around, who are - for the duration of the flight - no longer in their roles as father or mother, boss or employee, but simply a pilot. Flying changes the perspective. You zoom back, look at the word from a distance and see how beautiful it is - and how insignificant the bustle just a few hundred feet below.“

– from: Lisa Gast: Ein Jahr auf den Kanaren, www.lisa-gast.com

See you UP in the sky!

Top: training flight in the Dolomites • Photo: Andreas Schubert
Top right: winter sunset soaring at the Wasserkuppe • Photo: Lisa Gast
Top left: thermaling in front of the the Peitlerkofel, South-Tirol • Photo: Andreas Schubert
Below: Hike & Fly tour with Papillon • Photo & Guide: Felix Wölk
Bottom: Unforgettable impressions that can only be experienced with a paraglider
Back cover: Papillon Paragliding over the “Lüsener” alp • Photo: Felix Wölk

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Authors:	Paul Seren Andreas Schubert Anna-Lena Trabert
Proof-reading:	Sinje Meyer
Translation:	Lisa Gast
Design:	Lisa Gast Marc Niedermeier
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