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Turbulence: The Invisible Hazard

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Atmospheric turbulence can be a significant hazard when flying a ram-air canopy. It is important for all skydivers to understand the nature of turbulence and its potential effects on a canopy in flight. Skydivers should know how to avoid turbulence, but must also understand effective techniques for flying in turbulence if it is encountered.

Some knowledge of **basic aerodynamics** is helpful when discussing turbulence:

When flying a canopy you feel **relative wind** created by the movement of your body and canopy through the air.

Lift is generated by the flow of relative wind around the canopy. The speed of this flow (airspeed) can affect the amount of lift generated by the wing.

Angle of attack is the angle at which the relative wind intersects a particular section of a wing. As with changes in airspeed, changing the angle of attack can affect the amount of lift created. In normal flight the wing will have a **positive** angle of attack. If the angle of attack at a particular section of the wing reaches **zero,** that part of the wing will not create lift. An extremely high **(critical)** angle of attack will cause the wing to stall. A **negative** angle of attack can cause lift to be created in the "wrong" direction. For example, aerobatic planes are able to fly inverted by maintaining a negative angle of attack.

The movement of air across the ground can be called **atmospheric wind. Under normal conditions, atmospheric wind only affects the speed and direction of the canopy's movement across the ground.** In spite of the beliefs held by some jumpers, a steady wind will not affect the canopy's airspeed, angle of attack, or any other aspect of its aerodynamic performance in flight; neither you nor your canopy will be able to "feel" the atmospheric wind when you are flying. The only wind the canopy or the pilot will normally feel in flight is **relative wind** created by the movement of the canopy through the air.

Velocity is a combination of speed and direction. If the speed of the wind changes, the direction changes, or both change at the same time, we can say there has been a change in the velocity of the wind.

Turbulence occurs when there are sudden, abrupt changes in the velocity of the atmospheric wind. Unlike steady wind, turbulence **can** change a wing's airspeed and angle of attack, thereby altering the lift produced by the wing. These changes may only affect a certain part of the wing, or they may affect the entire wing at once. Turbulence can cause a canopy to slow down, speed up, turn, climb, or dive, and can also partially or severely distort the shape of the canopy.

Types of Turbulence:

If you stay in one location, and the velocity of the wind changes at that location, we call this a **gust.** The strength of a gust is determined by the difference between the sustained wind speed and the peak (gust) speed. Larger differences usually create more hazardous flying conditions.

If you move from one location to another and there is a significant change in the velocity of the wind between those two points, we call this **wind shear**. You experience wind shear on days when the wind is very strong when you first open your canopy, but is much lighter once you descend below a certain altitude. Another example occurs when the winds come from a certain direction above a certain altitude, but come from a different direction below that altitude. These are examples of large-scale wind shear: you might experience the same effect at the same altitude for many miles in all directions, and the same condition might exist for several hours or more.

Other types of turbulence involve wind shear or gusts on a smaller scale. The disturbance is confined to a smaller area, lasts for a shorter period of time, or varies significantly from one moment to the next. Some examples are:

> **Mechanical** – turbulence at low altitudes created by obstacles such as buildings, trees, and hills. Mechanical turbulence usually becomes more severe in stronger winds, and can be a significant hazard during approach and landing.
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> **Wake** – turbulence created by rotating vortices that extend some distance behind a wing in flight. During approach and landing the wake from other canopies or aircraft can be as significant a hazard as mechanical turbulence.
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> **Wind Gradient –** a continuous reduction in wind speed at lower altitudes caused by friction between the air and the ground. A wind gradient's effects on a skydiving canopy are usually not severe, but may be the cause of an unexpected, steady acceleration during the last 50-100 feet (15-30 m) of the canopy descent.
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> **Thermal –** rising masses of air often caused by surfaces on the ground that radiate more heat than the surrounding terrain. In most cases (not all, but most), isolated thermals do not create a significant hazard for skydiving canopies.
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> **Dust Devil –** a rotating mass of air resembling a small tornado. They usually occur in hot climates and can be extremely dangerous for skydivers. Dust devils are actually created by thermal activity, as are certain other forms of turbulence, but when skydivers talk about "thermals" they are usually referring to the more benign type of activity described in the previous paragraph.
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> **Thunderstorms –** create many forms of turbulence that can be very severe and dangerous to all types of aircraft.

Turbulence is generally classified as **light, moderate, severe, or extreme**. These classifications are usually based on the effects experienced in an aircraft, as reported by the pilot flying the aircraft. Skydiving canopies are generally affected by turbulence to a greater degree than most rigid-winged aircraft. Turbulence that we consider severe might only be considered moderate by other pilots.

Avoiding Turbulence:

Mechanical turbulence is one of the most common types experienced during canopy flight, and can also be the most dangerous. It is important to avoid areas where significant mechanical turbulence might be encountered. This includes the areas directly above, upwind, and downwind of any large objects on the ground.

The actual size of the "turbulent zone" around an obstacle will vary based on the exact size and shape of the obstacle, the presence of other obstacles in the area, and the strength of the wind. A good estimate can usually be made based on the object's height. In moderate to strong winds, turbulence may be encountered above an obstacle at an altitude equal to twice the obstacle's height. Turbulence may also be encountered on the upwind side at a distance equal to one or two times the height of the obstacle. On the downwind side, turbulence may be encountered at a distance equal to at least **ten times the height of the obstacle**.

As an example, if we use a building that is 30 feet (9 m) tall, you could encounter turbulence when flying above the building at an altitude of 60 feet (18 m). You might encounter turbulence if you flew within 30 to 60 feet (9-18 m) of the building on the upwind side. On the downwind side, you could encounter turbulence more than **300 feet** away from the building (90 m).

It should be remembered that these numbers are just rough guidelines. Some texts state that turbulence may be felt as far away as **twenty times** the height of the obstacle on the downwind side. Unfortunately, skydivers often underestimate these distances rather than using more conservative estimates. Jumpers will often land close to large objects in moderate to strong winds, and many seem surprised when they encounter strong turbulence while doing so.

Wake turbulence extends back along the flight path of a canopy. Significant effects may be felt more than 50 feet (15 m) away from the canopy that generated the wake. Wake turbulence normally descends and dissipates quickly, but it is still possible to encounter it along a canopy's flight path several seconds after the canopy has passed. It is important to avoid flying close behind another canopy at lower altitudes, particularly during the final approach and landing. Other types of aircraft can generate even larger, stronger, and longer lasting wake turbulence than a canopy does.

Thermals are often encountered on hot days above surfaces like asphalt. Although exceptionally strong thermals may be encountered at some drop zones, in most cases thermals pose a minimal risk compared to other hazards. Unfortunately, jumpers often say they hit a "thermal" when in reality they experienced a different type of turbulence, such as mechanical turbulence coming from obstacles upwind of the landing area. This can be a problem if it causes someone to take unnecessary risks while trying to avoid these supposed "thermals" later on. For example, a person might start landing dangerously close to some obstacle in order to avoid flying over a taxiway. It is usually not wise to compromise other aspects of safety in order to avoid thermals.

Although thermals by themselves are not usually hazardous, dust devils are a different story. Like a tornado, a dust devil may create a rotating, visible column of sand and debris; however, the dust devil may actually extend hundreds or even thousands of feet higher than this visible section. In some cases a dust devil may not be clearly visible at all. Dust devils normally move with the wind, so if you see one it is usually best to fly away from it in an upwind or crosswind direction. Information and advice from experienced local jumpers can be very valuable in places where these phenomena are common.

Thunderstorms are created by large-scale thermal activity in the atmosphere and produce severe turbulence that can extend a significant distance from the visible portion of the storm. Any time there are thunderstorms in the vicinity, or it appears that one might be developing, keep a close watch on the weather and use good judgment before boarding the aircraft. Large, heavy aircraft like commercial airliners are much more resistant to the effects of turbulence than skydiving canopies, but even the pilots of these aircraft normally try to remain several miles away from large thunderstorms. As with dust devils, advice from experienced local jumpers can be valuable in areas where thunderstorms are common.

Flying in Turbulence:

In some situations turbulence can cause a canopy to "collapse," or suddenly lose its normal shape. Because this can be the most startling and noticeable effect of turbulence, skydivers often focus on the need to keep a canopy "pressurized" in turbulent conditions. Unfortunately this philosophy can have undesirable effects.

For example, many skydivers have been told that if they experience turbulence they should apply 25% to 50% brakes in order to keep the canopy from collapsing. This did seem to help some early ram-air canopies fly more smoothly in turbulence, but most modern designs actually handle turbulence better while flying at full glide. A modern canopy may actually experience more significant effects from turbulence when flown in brakes.

It is also important to realize that a canopy can be severely affected by turbulence without collapsing or distorting. Turbulence may cause sudden, unwanted heading changes or a sudden loss of altitude with or without any visible distortion of the wing. In fact, many of the effects that we experience under canopy in turbulence are actually similar or identical to those experienced in a rigid-winged aircraft. Rather than resulting from a loss of pressure, these effects can be explained as sudden changes in airspeed or angle of attack affecting either the entire wing or part of it.

As in any other situation, flying the canopy should be your main priority in turbulent conditions. If the canopy suddenly starts to turn, dive, or drop you must be ready to react to these changes and keep the canopy on your intended flight path, especially if this happens near the ground. Even if the canopy does start to distort or collapse, in most cases only part of the canopy is affected and it will quickly recover on its own. Preventing the canopy from turning or diving will give it more time to recover. Trying to keep your canopy "pressurized," or trying to "re-inflate" the part of the canopy that has collapsed, may actually distract you from the more important task of controlling your heading and rate of descent.

If turbulence does cause the canopy to start turning or diving near the ground, use smooth but deliberate toggle inputs to:

1) **stop or reduce any sudden loss of altitude;**
2) **keep the canopy level and on heading, stopping any significant bank or turn; and**
3) **keep the canopy flying toward a clear, safe landing area.**

For example, if the canopy suddenly banks or turns to the right on final approach, smoothly but quickly pull the opposite (left) toggle as far as is needed to get the wing level and stop the turn. If you have enough altitude to do so safely, smoothly steer back on to your original heading.

If the canopy suddenly surges or dives during the last few seconds of your final approach you may need to start flaring early in order to stop the canopy from accelerating and minimize the altitude lost.

If you feel a sudden turn or drop after you start to flare, **keep flaring the canopy!** Focus on a clear area in front of you and try to make the canopy fly straight while you continue pushing both toggles down.

If the canopy starts to climb while you are flaring, focus on a clear area in front of you and **keep the canopy flying straight.** When the canopy starts to descend again, continue flaring.

Always be ready to perform a parachute landing fall (PLF) when landing in turbulent conditions. Turbulence may cause you to land much harder than you expect to, and a PLF may be necessary.

You should be ready to take any or all of these actions in case you encounter strong turbulence close to the ground; however, it is certainly not necessary to react to every small bump you feel. Flying at full glide will usually reduce the amount of turbulence you feel in the first place, and make the effects less severe. When making turns in turbulent conditions, particularly at lower altitudes, keeping the turns smooth and steady will also help. Quick, abrupt turns can make a canopy more susceptible to the effects of turbulence.

High-Performance Landings:

Jumpers who practice high-performance “swoop” landings sometimes feel less turbulence than those who perform more conservative landings. This suggests that there is an advantage to making a faster approach in turbulent conditions, but there can also be disadvantages.

First of all, if you do not normally make high-speed approaches then a gusty, bumpy day is probably not the best time to start practicing them.

Many jumpers use a turn to generate speed during a high-performance landing. As we mentioned earlier, a canopy can be more susceptible to turbulence during a turn. Particularly in turbulent conditions, jumpers who make standard, conservative approaches or smooth “carving” front riser approaches face less risk than those who make quick, snappy “hook” turns.

As was also mentioned earlier, the speed of the wind itself will not change the aerodynamic performance of a canopy, including the amount of altitude required to recover from a certain maneuver. This distance is known as the length of the **recovery arc**. Unlike steady wind, turbulence **can** affect the length of the recovery arc. Since the effects of turbulence are difficult to predict, jumpers making high-speed approaches should use extra caution whenever significant turbulence might be present in the landing area.

Front riser inputs distort the shape of the wing to some degree, and may make a canopy more susceptible to the effects of turbulence. If you feel the front riser pressure suddenly decrease during a high-speed approach, smoothly release the front risers and return to a more conservative flight mode.

If a canopy’s steering lines are too short it may “hobble” or “buck” when the front risers are pulled. Although this is annoying and can reduce the effectiveness of the front risers, it is usually not dangerous in smooth air; however, the hobbling may be exaggerated by turbulent conditions, possibly to the point of being dangerous.

Effects of Canopy Size and Wing Loading in Turbulence:

Large, lightly loaded canopies and small, highly loaded ones each have certain advantages and disadvantages in turbulent conditions.

Large Canopy and / or Low Wing Loading:

Disadvantages: the jumper will usually have a "bumpier" ride. The canopy may distort or "breathe" more than a smaller canopy with a higher wing loading.
Advantages: turbulence will usually have less effect on the canopy's overall flight path. Any unexpected turns or dives usually develop more slowly, giving the jumper more time to react. The canopy might not react as radically to a partial collapse.

Small Canopy and / or High Wing Loading:

Advantages: the jumper will often have a smoother ride and feel fewer "bumps" in turbulent conditions. The canopy may not "breathe" or distort as much.
Disadvantages: if the jumper does experience significant turbulence the effects on the canopy's flight path will probably be more radical. Unexpected heading changes may happen very suddenly, and the jumper will need to react quickly to prevent excessive altitude loss. A hard landing is likely to cause more pain and damage.

Some canopies have specific advantages over others in turbulence, just as some aircraft have advantages over others, but **anything that flies can be affected by turbulence.** Every jumper should understand the specific advantages and disadvantages of the canopy he or she chooses to jump and the particular risks he or she may face when flying in turbulent conditions.

The Importance of Good Judgment:

It is important to exercise good judgment whenever turbulence may be present. You should evaluate the landing conditions and the amount of risk you will face by jumping in those conditions. How strong are the winds? Are they a lot stronger than any you have jumped in before? Are other jumpers having a hard time dealing with the conditions? Consider your current skill level and previous experience. Are jumpers with more experience than you staying on the ground? Is it really worth taking extra risks just to make a few extra jumps, or is it better to wait until the conditions improve? Even if the DZ is willing to send a load up, and others are willing to jump, you shouldn't feel compelled to trust other people's decisions if your own instincts are telling you to stay on the ground.

Conclusions:

Education is an important defense against the hazards of turbulence. Skydivers should understand the causes of turbulence and its potential effects on their canopies. We should also know how to avoid situations where significant turbulence might be encountered.

Preparation is also necessary. Every jumper should understand the proper procedures to follow if turbulence is encountered.

Evaluation and **good judgment** are also crucial. The best skydivers might take calculated risks for the sake of challenging their skills, but they will also avoid unnecessary risks that provide little or no real reward.

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