

BASIC SAILPLANE AERODYNAMICS

Part 9: GROUND EFFECT

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Bruce Campbell in Discus A "Delta One"; *Photo David Francis*

Ground Effect (Would you bet on it?)

A high performance sailplane, racing fast and low to the finish line, streaming water ballast, just high enough to clear obstacles like power lines, trees, and fences is an impressive sight and entertaining for the onlookers. It 's great fun for the pilot too!

Some pilots believe that this spectacular manoeuvre boosts a sailplane's performance through **aerodynamic ground effect**. Well, the truth is that the gain from ground effect is, at most, infinitesimal. The only tangible gain comes from burning off final glide safety height once the pilot is satisfied the airfield can be reached and the landing achieved with minimal risk. Ground

effect only comes into play towards the end of a very low altitude run at about 6 to 10 feet and when the sailplane has slowed to a far more modest speed. At this stage the L/D performance of the sailplane increases and extends the distance the aircraft is capable of gliding before running out of flight energy and touching down.

By now, I suppose I may have succeeded in outraging those pundits who embrace ground effect as one of the secret weapons of high performance soaring. But stay with me. Aerodynamic ground effect really exists and can be very useful for sailplane pilots in certain circumstances. It also entails some hidden hazards especially during take off or in stretching a low energy final glide.

Ground effect can increase “float” distance prior to touch down. Judicious use of ground effect can help pilots deal with tight landing options. Using ground effect to extend the float prior to landing is a sound technique for landing long towards an obstacle. The trick is to avoid extremes like flying unnecessarily fast, leaving it until the last possible moment to deploy airbrakes, bouncing dangerously because of premature touch down, or showing off by floating up too close to the obstacle. And don’t be in any doubt; many a glider pilot has come to grief, particularly on hangar flights, by doing one or all of the above.

The extended “float” is a useful training tool for flight instructors to help trainees sort out flare technique and landing problems. Student pilots who are having difficulty in judging their hold off attitude and height after rounding out frequently benefit from exposure to the technique under guidance from a skilled instructor. Similarly, pilots can use ground effect in an extended float to refine their airbrake technique in bleeding off energy when operating on sloping runways.

In another application, pilots who find themselves low on final glide sometimes resort to diving near the ground to gain the benefit of the performance boost coming from ground effect and wind gradient-reduced headwind. Sounds good, doesn’t it? There are caveats, however. The facts are that the gain in distance is quite small, around 200 to 300 metres in zero wind conditions and the profile that must be flown is rather precise. The descent requires a smooth dive from about 200 feet to round out and then to fly with steadiness and accuracy very near the ground without actually contacting it or any other solid objects until ultimate touchdown. Mind you, there is not a lot of future in putting yourself in a position where you need to rely on this strictly emergency technique. It’s worth emphasising that stretching the glide using ground effect and then attempting to zoom over a fence or trees is particularly hazardous and a rather stupid way to risk your life.

So, there are several practical, if demanding and potentially risky, ways of using ground effect in gliding. But, just what is this apparently magical source of aerodynamic energy?

Ground Effect – Aspect Ratio Influence

Ground effect on wings is sometimes described as having two main characteristics: “span dominated” and “chord dominated”. Aircraft with long, slender (high aspect ratio) wings benefit particularly from reduced induced drag when flown in ground effect. Low aspect ratio wings, especially on low wing aircraft benefit from an “air cushion” under the aircraft that effectively reduces the sink rate and produces an extended “float”.

Yes, **it's true: less drag and reduced sink**. Ground effect actually improves L/D performance. But wait. Before you get too excited and start fence hopping in your sailplane, it's worth reading the fine print.

Span Dominated Ground Effect

Part 2 of this series (*Soaring Australia* September 2005) dealt with induced drag which occurs because of the lower pressure above a wing and the flow of higher pressure air from underneath the wing to the upper side around the wingtip. This airflow creates a vortex at each wing tip. The energy loss in these wing-tip vortices is called induced drag. In a way it's like dragging a miniature tornado along behind each wingtip.

Aircraft such as sailplanes, which have a high aspect ratio, generate relatively weak wingtip vortices and associated induced drag. This is because low-pressure areas at the wingtip are smaller as a consequence of being more distant from the main surface of the wing compared to a low aspect ratio aircraft. In *Mechanics of Flight*, Kermode explains that “the higher the aspect ratio the less is the **proportion** of air” split by the wing that flows inwards above and outwards below the wing tip, thus forming vortices. He goes on to say that “**the greater the aspect ratio**, the less violent are the wing-tip vortices, and **the less the induced drag**”. The loss from these vortices in sailplanes is still quite substantial though, accounting for about 50% of drag at best L/D airspeed. It increases to around 70% at lower speeds and reduces at higher airspeeds.

What has all this to do with ground effect? You might well ask. The answer: quite a lot.

When an aircraft is flown close to the ground there is not enough space to allow the vortices to develop fully. The result is less leakage of pressure from below the wing, so the vortices are weaker, reducing the amount of induced drag. The pressure beneath the wing also increases because the proximity of the ground squeezes air outwards, flattening and widening the pressure pattern compared to the pattern at higher flight levels (Figures 20 & 21). At the same time the wingtip vortices are pushed outwards. The wider spread

pattern gives the very real benefit of effectively increasing the sailplane's wingspan – and its virtual aspect ratio.

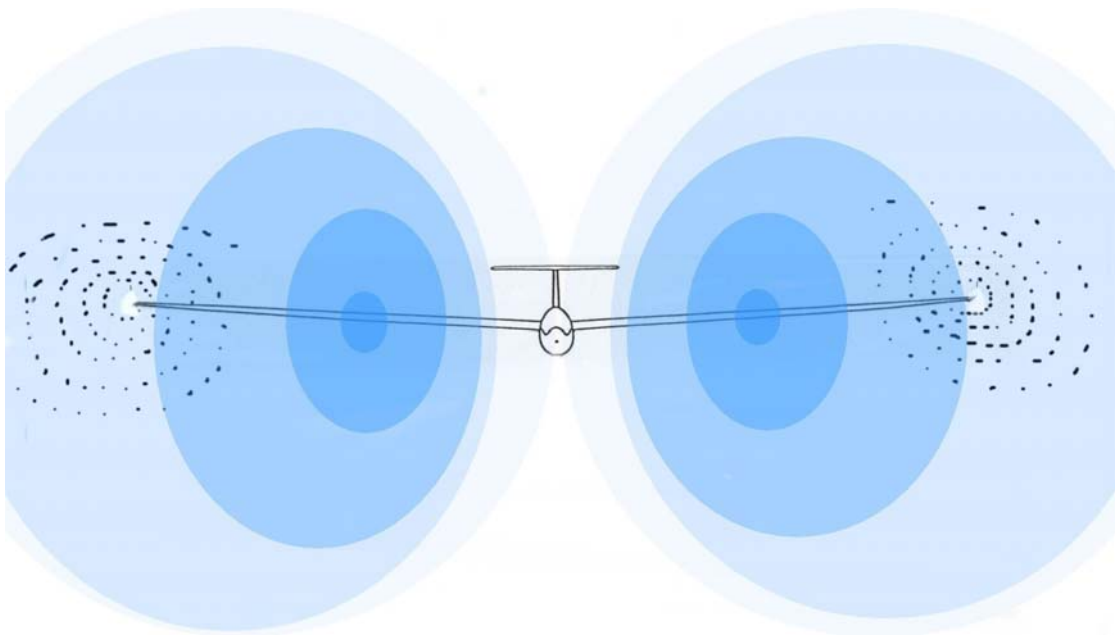


Figure 20: Approximate pressure and wingtip vortices pattern of a sailplane at best L/D well above ground (notional only)

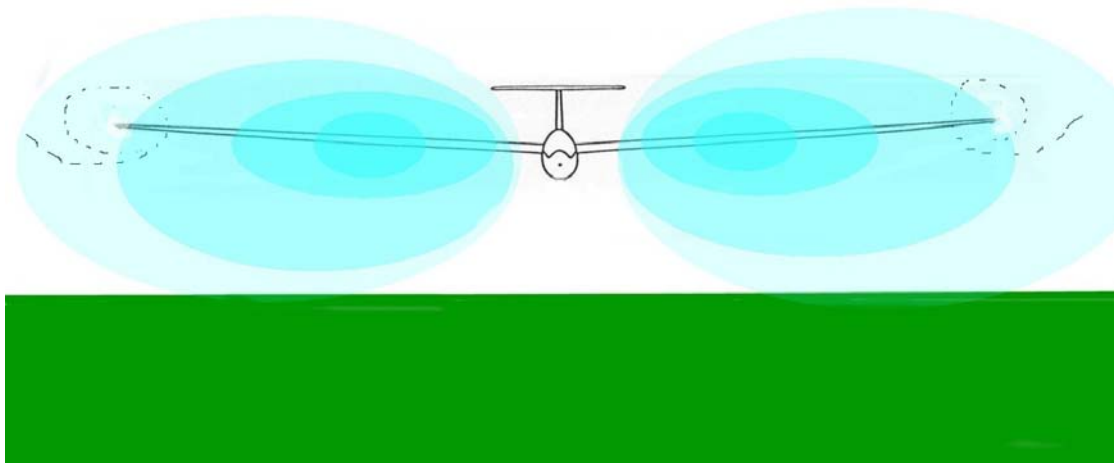


Figure 21: Approximate pressure and wingtip vortices pattern of a sailplane at best L/D 10 feet above ground (notional only)

According to theoretical work by Wieselsberger in the 1920s, induced drag reduces to approximately 50% at a ground clearance of 10% of the wingspan. While there may be some fuzziness in quantification, the net result of span dominated ground effect is clear. There is a reduction in induced drag and the temporary benefit of increasing the effective wingspan of your sailplane. But bear in mind this only happens very close to the ground.

Chord Dominated Ground Effect

As a wing approaches the ground the high pressure beneath the wing increases because of the compression of air between the wing and the ground. This 'air cushion' effect causes a landing aircraft to tend to 'float' briefly before touchdown. This phenomenon was exploited in the 1920s by passenger carrying seaplanes, such as the Dornier DO-X, which could only cross the Atlantic by flying just above the sea. Some navies and ferry operators still use wing in ground effect (WIG) vehicles. These curious half ship, half aircraft hybrids have wings shaped to maximise downwash and to trap the air cushion.

Pilots of low wing aeroplanes are well aware of ground effect "float"; some uncomfortably so, if they make their approach with excessive airspeed. Compounding the problem of excess energy with ground effect can be a real embarrassment to say the least!

The air cushion ground effect is most pronounced in low wing, low aspect ratio aircraft with large wing areas. It is virtually zero in sailplanes because of their narrow chord, high aspect ratio wings.

Ground Effect During Take Off – A Potential Killer

The "boost" from ground effect can give a false sense of security to pilots of heavily loaded aircraft during take off. The consequences can be lethal.

Factors like short fields, wet grass, high density altitude, adverse winds and flight path obstructions can tempt pilots to drag their aircraft prematurely into the air; risky in any circumstances, but particularly so if the aircraft is overloaded.

Any overweight, underpowered aircraft is at hazard if ground effect plays a significant part in its take off performance. This includes self-launching sailplanes. What can happen is that the reduction of drag in ground effect gives the pilot a sense of excess power for the climb. If there is insufficient power to sustain a safe speed the aircraft slows down. If the pilot attempts to raise the nose to keep climbing, more airspeed is eroded. Persistence will inevitably lead to the aircraft sinking back to earth, sometimes inconveniently

and potentially, disastrously. The proper technique is to stay low in ground effect until a safe airspeed is attained.

Heavily ballasted sailplanes on aero tow launch are particularly vulnerable. If the pilot of the tow plane is unaware that the sailplane is heavy and initiates climb out after take off before the sailplane has achieved the relatively high airspeed it needs (typically 70 knots), the sailplane pilot is placed in a dangerous situation.

At lower speeds the sailplane feels to be flying comfortably near the ground despite the downwash and prop wash from the tow plane. In part, this is because ground proximity is applying a smoothing effect to the “dirty air” behind the tug. Also, aileron control may be enhanced because of the lower required angle of attack at a given speed, a by-product courtesy of reduction in induced drag, which allows the wing to fly at a lower angle of attack for the same amount of lift.

This all changes as the sailplane suddenly comes out of ground effect at a relatively high nose attitude and angle of attack, still in the dirty air behind the tug. At best, the pilot feels very vulnerable because of the sailplane’s low energy state particularly if the tow rope should let go. At worst, the pilot is left fighting to avoid stalling near the ground while still attached to the tow rope - a very unpleasant situation for both the tow plane and glider pilots. There is also a risk that the tug pilot might interpret the mushing of the sailplane and attendant tail down force on the tug as a cue to abort the launch.

Ground Effect in Summary

So called “span dominated” ground effect reduces induced drag and creates a virtual boosted wing span. Less relevant to sailplanes, “chord dominated” ground effect compresses air under the wings, generating a kind of “air cushion” and reducing the rate of sink.

On the face of things then, ground effect promises a lot to the adventurous sailplane pilot: reduced drag, increased virtual wing span and reduced sink. A boost in performance for your sailplane resulting from ground proximity - something for nothing it seems.

Almost too good to be true don’t you think?

Now, Some Solid Research Findings

Well, true or not for aircraft in general, there is a view based upon rigorous testing and associated analytical data which casts doubt on the usefulness of ground effect for sailplanes.

Research by Nathan F. Jones in 1988 as part of a United States Air Force Test Pilot School project *Glider Ground Effect Investigation* demonstrated that the benefits of ground effect on sailplanes are quite limited. The study

involved 122 scientifically measured sorties by a Grob Twin Astir and an L13 Blanik. Its **main conclusion** was: “...ground effect is not practical or safe to use in extending glide range”.

Significantly also, Jones concluded that: “...penetration airspeed (appropriate MacCready ring setting) glides provide maximum glide range under normal conditions”. That is, pushing over on long final approach at around 280 feet and diving the sailplane to 10 feet or so above the surface to establish in ground effect does not gain any glide range more than what would have been attained had the ring setting airspeed been maintained. The experimental data confirm that ground effect only increases sailplane glide performance when the aircraft is flown at relatively low airspeeds close to the ground. This is consistent with the reality that induced drag is greatest at low speed. Although low and fast may look good, in practice ground effect does not come into the performance equation in any significant way.

To be fair, Jones also noted that better performance in ground effect can be expected from sailplanes with “...long wingspans, high wing loadings, low parasite drag coefficients and high induced drag factors”. It goes without saying that there is a world of difference between the humble Blanik, the Twin Astir and, for example, an ASH 25. At the same time it seems reasonable to suggest that the principles would remain the same, although the magnitudes would vary.

Reality Check

Now here’s the thing. Ground effect is a useful means of reducing induced drag and gaining temporary improvement in a sailplane’s performance. It is there to be used in the right circumstances.

That said, it is vital to keep the whole business of using ground effect in perspective. Low flying entails a special set of risks - aerodynamic and human. Flight close to the ground and observed relative motion can seriously impair a pilot’s perception of ground speed and distance. Pilot adrenaline levels are very high, and everything is happening quickly. Reduced lookout for other traffic, unexpected obstacles like unseen wires and fences, as well as startled birds and stock (frightened sheep really do jump!), can provide unwanted split second challenges for a pilot on a low level run. So, know the risks and be sure you can manage them before committing to reliance on ground effect.

Ground effect notwithstanding, marginal, low energy final glides are very dangerous. Whether you dive for speed in a last minute attempt gain enough kinetic energy to zoom over fences, trees or other obstacles, or simply try to float over them at minimal airspeed with no kinetic energy margin, you are risking your neck in a big way. **Don’t do it.** Choose a safe outlanding option while you have enough height to make a sensible decision.

Aerodynamically, pilots should bear in mind that ground effect adds nothing to performance in high speed finishes. The actual saving in drag is minimal because induced drag is low in high speed flight. Making matters worse, profile drag increases with the square of the speed and ground effect has no bearing on profile drag. Energy is wasted in a high-speed dive to burn off altitude on final glide. This is a direct consequence of increased profile drag and because the benefits of ground effect do not come into play until the sailplane is ten feet or so above ground at fairly low airspeed. All that extra speed and associated profile drag simply means the pilot has squandered time on task by accumulating more altitude than needed.

So, there are small performance benefits; but they are nowhere near as impressive as the flight path of the sailplane suggests. On the other hand, pilots need to weigh carefully the risks to themselves and others near their flight path when deciding how best to use their final glide safety height.

And don't forget; in some circumstances high speed flight near the ground is illegal.

Summary

Overall, aerodynamic ground effect offers instructing and landing finesse benefits. It can also save your skin in undershoot emergencies, although there are serious risks that might result in the opposite outcome. For contest pilots, there are minor performance gains; unfortunately, these tend to be overstated. On the negative side, for heavily loaded sailplanes ground effect can create a serious take off problem. For all sailplanes, low energy floats with transitions into and out of ground effect are hazardous.

Regardless of where and when ground effect is relied upon, to use it safely and effectively demands realistic technical understanding, self-knowledge and discipline on the part of the pilot as well as skill, currency and situational awareness.

Further Reading:

Kermode, A.C. *Mechanics of Flight*, Ninth Edition, Longman Scientific and Technical, UK Ltd., 1987

Jones, Nathan H. *Glider Ground Effect Investigation Thesis*, Department of The Air Force Air University, Wright-Patterson Air Force Base Ohio, USA, 1989. Storming Media, Washington DC 20002.

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