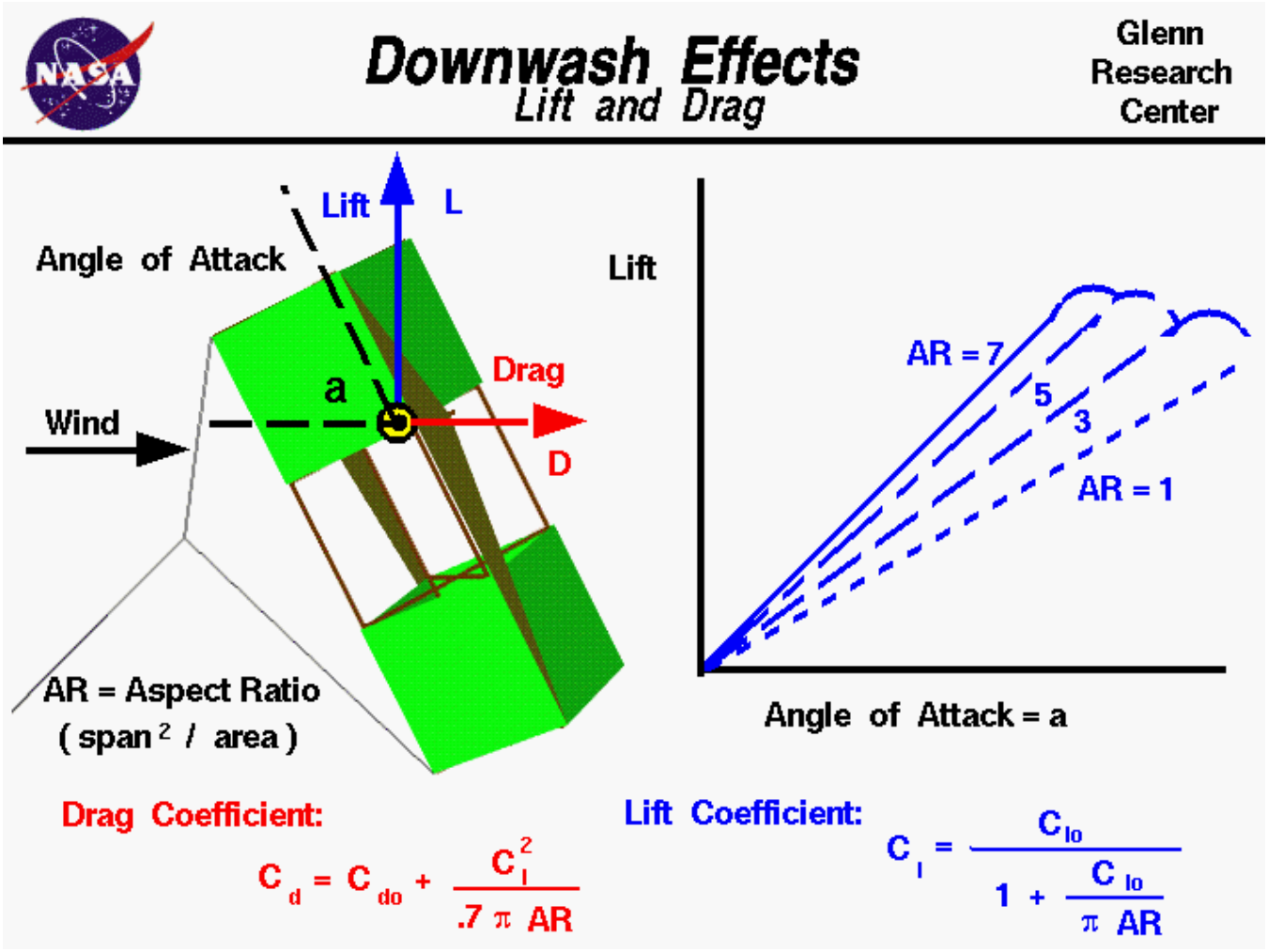
Ground Effect

One of the most misunderstood aerodynamic effects is called ground effect. It is the phenomena when an airfoil is operating close to a boundary such as the ground or water.

In many general aviation airplanes this effect produces greater lift and less drag for a given angle of attack. As we operate an airfoil close to a boundary there is a modification of the airflow such that the upwash, downwash, and wingtip vortices are impacted.

But first, let's go fly a kite:



The lift coefficient, C_{lo} is equal to the 2*pi*a. Likewise, the drag coefficient, C_{do} is equal to 1.28*sin(a), where a is the angle of attack. Without developing these equations in depth, one can see that both lift and drag increase with an increase in the angle of attack. Also note that as we increase lift, drag also increases as a squared effect (see the squared C_l term in the drag equation).

The terminology for this effect is downwash. Thus it is analogous with what is more commonly referred to as induced drag, but with an added twist, it refers to the fact that this induced drag has a vector component. The following picture illustrates this a bit better. In this example an airplane at a higher

altitude is flying out of ground effect, but it's downwash (induced drag) is a vector that is backwards, downwards, and (although we can't see it) outward.

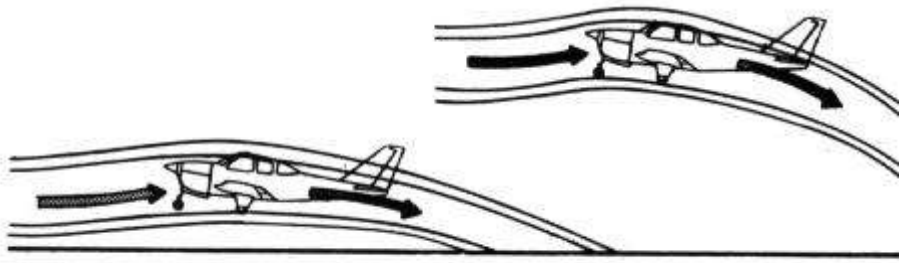
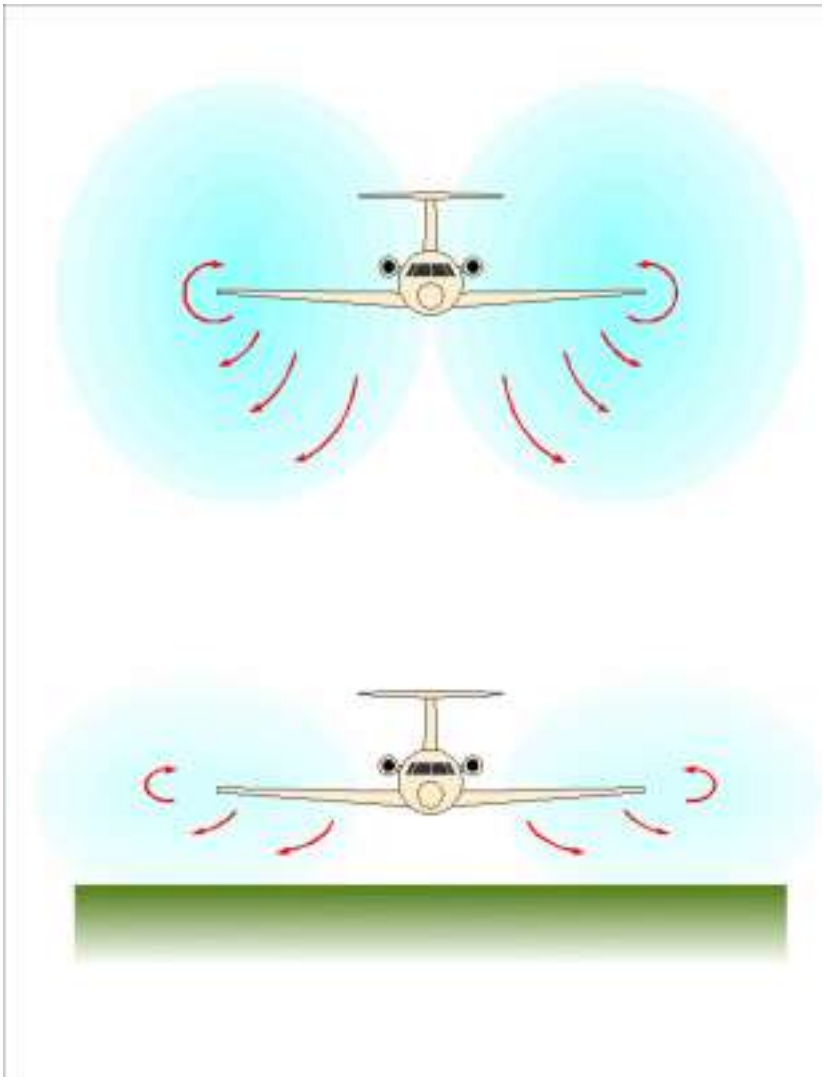


Figure 17–19 Ground Effect Changes Airflow

As the airplane gets closer to the ground, this downwash is modified such that it contributes less of a vertical opposition to lift.

Another component of this downwash is wingtip vortices. This is caused by the higher pressure of the air at the wingtips going upwards to meet the lower pressure of air at the top of the wing tip.

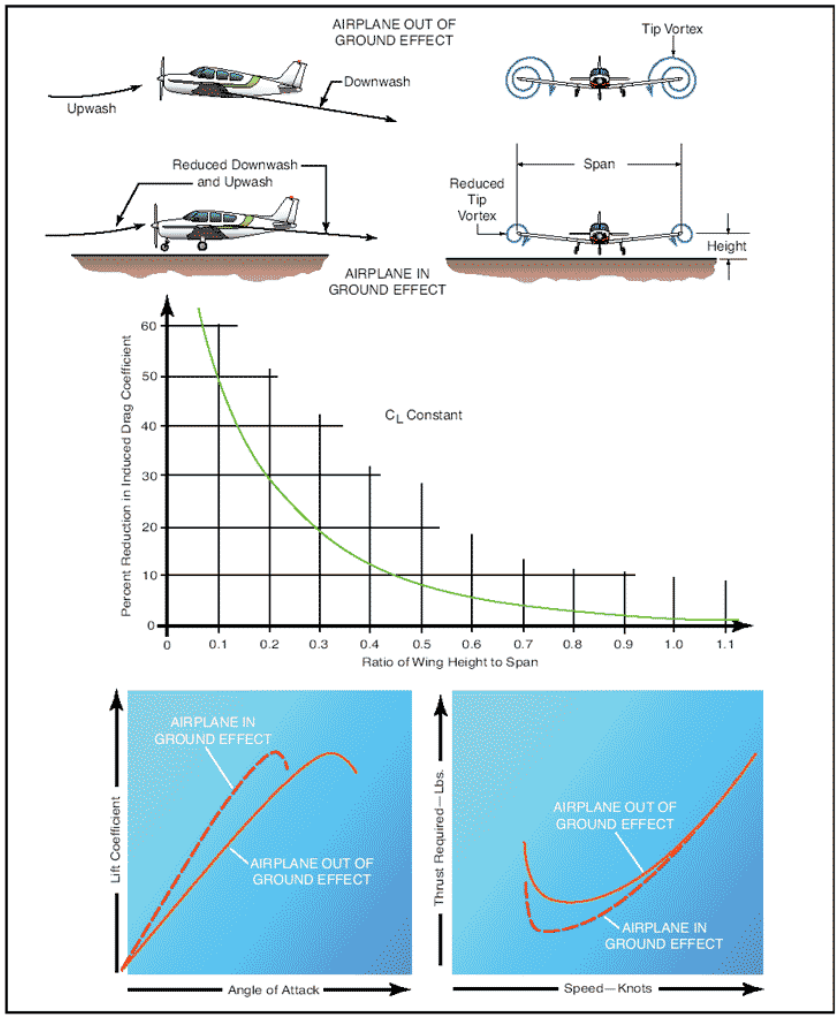


Ground Effect

Again, as the above picture shows, when flying in a boundary situation, these vortices are modified and not allowed to develop and drag is reduced. It is important to note that downwash is along the entire trailing edge of the wing and the wing tip, it is just easier to see the wingtip vortices and use these to explain ground effect.

Some fixed wing aircraft have winglets designed to reduce these wingtip vortices. (see below figure)

Ground effect is at its most when flying close to the ground. Indeed, when less than half a wingspan, the effect is most pronounced as shown in the graphs below.



Ground Effect

Ground effect impacts operations:

- Is most pronounced (noticeable) when airspeed is on the left side of the L/D_{max} curve since it is a reduction of induced drag
- If you rotate prematurely (such as in a soft field takeoff) the airplane will leave the ground earlier (we must modify our soft field takeoff to stay within ground effect and accelerate to a safe climb airspeed – typically V_x)
- During takeoff, if you climb at too slow of an airspeed, when you leave ground effect it may cause the airplane to sink (perhaps rather abruptly) back to the runway
- During landing, excess speed in flare may cause floating, the Diamond is particularly susceptible to this
- If approach speed is too high, landing distance will be longer due to float caused by ground effect
- More noticeable in low-wing aircraft
- Ground effect diminishes/increases as airplane goes higher/lower

For a different, but really good, discussion on ground effect you might want to go to this link:

http://www.avweb.com/news/airman/185905-1.html?type=pf