Fast and loud—how to create sonic booms and curious clouds

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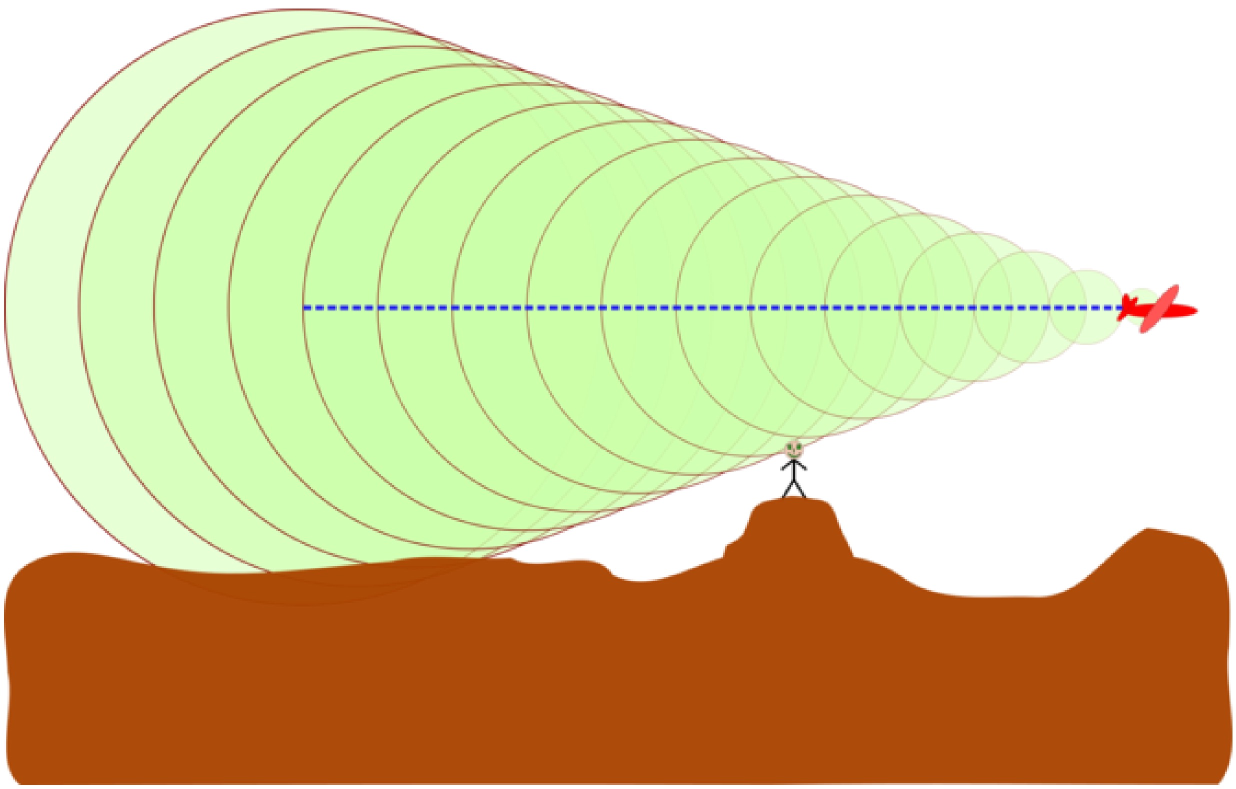

The sonic boom cone effect. Credit: Melamed katz, CC BY-SA

Growing up beneath the Concorde flight path, I learned early on that if you heard its characteristic roar overhead you had to look far towards the horizon to see it. If you were lucky, you would see Concorde first. You could then count the seconds before you heard its noise to get an idea of how high it was – like you might do with thunder and lightning to check whether the storm is incoming or moving safely away.

But Concorde was also known for making another sound – the "sonic boom" – a loud bang that happens when supersonic aircraft break the sound barrier. This was what residents along New York's East Coast recently reported when the US Department of Defence conducted flight tests over the Atlantic.

Concorde was impressive, a passenger jet that at a maximum speed of 2,180 km/h could travel at twice the speed of sound. It could fly from Paris to New York in a few hours but unfortunately most people on land didn't get to hear the sonic boom that happened when it overtook the speed of sound out over the ocean. As a child I was fortunately able to hear it as military aircraft from the neighbouring air base regularly obliged until better environmental regulations put an end to it. However, as the now retired Concorde isn't the only aircraft to be able to break the sound barrier – there are still chances to hear it.

That boom, boom, boom

So how does sound travel and what causes the sonic boom? Listening for thunder, we use the fact that sound waves in air travel at roughly 340 meters a second. So if you see lightning, followed by a roll of thunder three seconds later, you know the storm is roughly a kilometre away. If the delay becomes less than three seconds, it is best to seek shelter as it means the storm is coming closer. And if it becomes longer than three seconds, you know it is moving away.

The speed of sound varies slightly, for example in humid air or fog. In water it is five times slower than in air, but still very fast.

The speed of sound is referred to as Mach 1, in honour of Austrian scientist Ernst Mach, who investigated it first. Concorde was the first commercial aircraft to reach Mach 2 routinely and for the last half-century, some planes, such as the experimental X-15 rocket plane, have been able to reach speeds of Mach 6.

Compressing the air in front of it, an aircraft in motion creates bow and stern waves, much like a boat in water. As its speed reaches and then exceeds the speed of sound in air, the aircraft moves faster than the sound waves it has created. The waves in front are compressed more and more, until they get so close together that they combine to create a shock wave.

If the aircraft flies in a straight line at supersonic speed, the shock wave forms a cone, trailing away and becoming finer as it flies faster – this then creates a bigger shock wave. Someone on the ground won't hear anything until the trailing edge of the cone reaches them. They would first notice the high rise in sound pressure (a first boom) and then the return of the pressure to normal, which creates a characteristic second boom. A sonic boom is always a double sound but sometimes the two booms are so close together that they are perceived as one.

Now you see it

This loud boom is not the only way we know an aircraft has become supersonic. Water vapour is always in the air, in different quantities. When the aircraft flies through this air and makes it less dense in its wake, it decreases the pressure and makes it easier for the vapour to condense. These vapour cones are sometimes called "shock collars" and scientifically explained as a "Prandtl-Glauert singularity" (a good name to impress friends with).

As several shock waves pass through the air, water can condense between them, creating more complex patterns. These patterns will change with the shape of the aircraft (how easily it reaches and maintains supersonic speeds), the amount of water vapour in the air, but also according to how the shock wave might be affected by the topography (for example, if the sound waves are reflected off the hills as an aircraft flies low over them). So not only can airplanes be "fast'n loud", they also can create curious clouds if the conditions are just right.

Sonic booms are not restricted to planes, though. In 2012, Felix Baumgartner – who jumped from a balloon about 128,0000ft (39km) up – showed that humans in free fall also can go faster than Mach 1.

Closer to home (but hopefully not at home), a common bullwhip, if used expertly, can create a sonic booms, too. The end of the whip has much less mass than the handle section. When the whip is brought into action, the energy is transferred down the length from the handle to the tip, which can then travel faster than the speed of sound.

Even snapping towels have been proven to break the speed of sound if handled expertly. But no "curious clouds" have been associated with them – although perhaps a towel snapping in a sauna might do the trick. Now that would make for an interesting follow-up.

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