Contents photograph by Matthew Greeff Safaris

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REGULAR

ARTICLES

- **Cover:** A Merkel action sidelock over and under double rifle in 7x65r caliber, property of Hendrik Frauehauf. Engraved by himself in 1993-1994.
- **Cover photograph:** YVDM • **Cover design:** Nadia du Plessis

CHRIS BEKKER

Factors affecting bullet drag

Part 1

How can a little air significantly slow down a bullet? Well, think about pedalling a bicycle into a strong headwind. That is just air, yet pushing against the headwind demands some effort, real energy on the cyclist's part. Bullets are also subject to this very same wind force. The cyclist has to power his way through nitrogen (about 78% of the atmosphere,) oxygen (21%), argon (just under 1%), carbon dioxide (0.039%), trace gases (0.003%) and water (about 2%) that we experience as "invincible" air. The fact of the matter is that all these molecules create friction and the colder they are, the more densely they are packed together, and so the bullet must expend more energy to fight its way through the resultant drag. On the contrary, hot air expands, thus reducing molecular density and thus drag. This is why bullets lose velocity because of air resistance or air drag, depending on air density that varies at different locations.

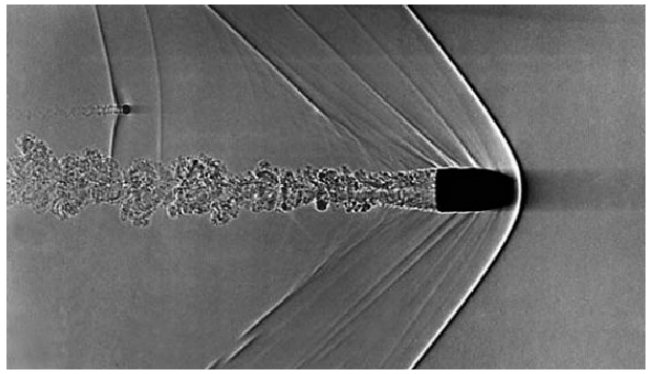
Air density is the weight of one cubic foot of air, but this weight is not the same all over the globe. The air is denser at sea level and thinner inland, the higher we move above sea level. Air exerts a pressure on the surface of the earth under the influence of gravity. The standard is pitched at sea level, at 59 degrees Fahrenheit, where the weight or density is 0.0765 lbs per cubic foot or a pressure of 14.7 pounds per square inch. The density of dry air at sea level is 1.2929 kg/m^3 or about 1/800th the density of water.

Calculating Air Resistance: Air resistance is usually calculated using the "drag equation", which determines the force experienced by an object (in this case the bullet) moving through a fluid or gas at relatively high velocity. It can be expressed mathematically as:

$$F_D = \frac{1}{2}\rho v^2 C_D A$$

In this equation, *FD* represents the drag force, *p* is the mass density of the fluid, *v* is the speed of the object relative to sound, *A* is the cross-section area, and *CD* is the drag coefficient. The drag is to the square of the velocity multiplied by the coefficient of drag. However, the coefficient of drag depends on the Mach number (velocity stated in terms of the speed of sound). In supersonic conditions, the drag is relatively high and decreases for subsonic conditions. The coefficient of drag is rather complex to calculate and most of the time only empirically available, and it depends on the exact geometric design of the bullet.

Temperature affects air density, with cold air being denser and hot air is less dense. Furthermore, higher ambient temperature also increases the pressure of a given cartridge load - e.g. a 30-degree Fahrenheit change in IMR powder temperature, will alter the velocity by 51 fps.



Bullet showing the air flowing around it, giving us a visual representation of air resistance.

Ammo exposed to direct sunlight will increase more in temperature than air would - e.g. a temperature of 140 degrees Fahrenheit is common, and in a closed vehicle it can reach 160 degrees Fahrenheit easily. Cold temperatures retard powder combustion - especially in arctic conditions. A temperature change of 17 degrees Fahrenheit will influence the air density the same way as an elevation change of 1,000 feet. As a rule of thumb, for every 20 degrees Fahrenheit of temperature increase, a rifle bullet will strike approximately ½" to an inch higher per every 100-yard increase in distance.

Also, **altitude** plays a role, as the column of air is lighter, the higher we go above sea level. Higher humidity also decreases air resistance, but it is so small that we can ignore it. When a rifle is sighted in at a low altitude and taken to a higher altitude, it will shoot higher, and the bullet's velocity downrange will also be higher, as the air is thinner at a higher altitude and therefore the drag is lower. As a rule of thumb, for every 5,000-foot increase, a rifle bullet will strike approximately ½" to an inch higher per every 100-yard increase in distance. Hunting Mountain Nyala in Ethiopia that is situated on a 9,000 ft. high plateau, where the mountains reach 14,000 ft., the hunter

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will have to re-sight his rifle if he is from somewhere else. Practically **air density**, as a single factor, plays a more significant role in slowing a projectile than differences in temperature and altitude, although they are all inter-related. A decrease in barometric pressure reduces the density of air. A decrease in temperature has the opposite effect. As hunters, we are not materially affected. However, Benchrest shooters, that want to hit the bull at a 1,000 yds., are more concerned with air resistance, cross-winds and bullet drop, whilst their bullets must always remain supersonic (above the speed of sound) to avoid the turbulence that would follow, should the bullet fall through the sound barrier.

Mountain Nyala (Tragelaphus buxtoni) male.

Altitude	Temperature	Pressure	Pressure Index
Sea level	59.0 degree F	29.53 inches Hg	100.0%
+3,000 ft.	48.3 degree F	27.02 inches Hg	91.5%
+6,000 ft.	37.6 degree F	24.68 inches Hg	83.6%
+9,000 ft.	26.9 degree F	22.50 inches Hg	76.2%

How would a bullet behave in a vacuum without any air resistance? A 150 gr .308 bullet fired straight up in the air at a muzzle velocity of 2,700 fps, will rise 9,000 feet, taking 18 seconds to do it, and comes back to earth in 31 seconds, connecting the earth at just over 300 fps. If the same bullet were fired in a vacuum upward at the same velocity, it would rise to over 113,000 feet (21.4 miles), taking 84 seconds to go up and 84 seconds to come down. That gives us an idea of what air resistance does to a bullet in flight.

Without air resistance, i.e. in vacuum conditions, the maximum range of a bullet would be achieved when the rifle is pointed upwards at an angle of 45 degrees. In real life though, the maximum range will generally be between 27 and 35 degrees, depending on the bullet's BC and its velocity. A 172 gr .308 calibre bullet with a BC of .560, launched at 2,600 fps has a maximum range of 5,500 yards. There is no point in doing this, though, as it could be dangerous without a backstop unless the shooter is convinced that nobody is in his line of sight.

For interest sake, here is a list of what constitutes standard atmosphere, as defined by the **International Civil Aviation Organization (ICAO)** in 1956, and are the mean conditions to be found at a latitude of 45 degrees, at sea level. Speer Bullets and Nosler Bullets are using ICAO standards.

Parameter	Imperial	Metric
Atmospheric Pressure	29.921 inches Hg	1,013.25 millibars
Temperature	59 degrees F	15 degrees C
Density	0.0765 lb./ft^3	1.25 Kg/M^3
Relative humidity	0 %	0 %
Velocity of sound	1,116.5 ft./sec	340.3 m/sec
Gravity	32.1741 ft./ sec^2	9.8067 m/sec^2

Note: 760 mm Hg = 1013.25 mbar = 1013.25 hPa. A decrease in temperature is equal to 0.65 degrees for every 100 meters (328 feet) of ascent.

Altitude (Ft)	Pressure (in Hg)	%
0 (Sea Level)	29.92	100.0%
1,000	29.86	99.8%
2,000	27.82	93.0%
3,000	26.82	89.6%
4,000	25.84	86.4%
5,000	24.90	83.2%
6,000	23.98	80.1%
7,000	23.09	77.2%
8,000	22.23	74.3%
9,000	21.39	71.5%

The US Army adopted a set of **standard atmospheric conditions**, also at sea level, known as **Standard Metro conditions**: - (essentially the major difference is in humidity percentage).

Parameter	Imperial
Atmospheric Pressure	29.53 inches Hg
Temperature	59 degrees F
Relative humidity	78 %

While the two standards are similar, it affects calculations and it changes the standard atmospheric density by about 1.8%. Under ICAO conditions the speed of sound is 1,116.5 fps and under Standard Metro conditions it is 1,120.3 fps at sea level.

Standard Metro conditions are mostly used when ballistic tables are prepared and published for commercial bullets, such as Sierra and Hornady. It is said that the difference between the two sets of standards, is not significant as it affects ballistic coefficients by less than 2 %. It should be clear by now, that we as hunters, very seldom hunt at Standard Metro conditions. Barometric pressure is continuously varying with changes in weather patterns. It is also interesting to note that the speed of sound is also less the thinner the air becomes.

It was Sir Isaac Newton who showed the relationship between humidity and density of air for the first time by stating that humid air is less dense than dry air. If one goes by the book, humidity is the water vapour present in the atmosphere, instrumental in predicting the chances of precipitation (rain, sleet, hail and snow), fog or dew.

Bullet shape does affect the drag that the air will have on the bullet, i.e. bullet drop and wind drift. The higher the ballistic coefficient (BC), the less the effect as the more streamlined bullet will cut the air with less resistance and so it will give a flatter trajectory. BC's are not a significant consideration for those hunters that hunt at distances less than 200 yards. Also, remember that a BC is not an absolute value ... it will change with different speeds, temperatures, altitudes and humidity ... that is why we revert to standard conditions when ballistic tables are published.

One USA manufacturer, Sierra, publishes three different BC's for their bullets, each valid in a specific velocity band. So, beware of ballistic charts - do not treat them as gospel. The mathematics of BC's are too complicated for the average reader, so there is little point in going into them. All we need to know is that the BC is the aerodynamic property of the bullet, and it is arrived at by dividing the sectional density (SD) of the bullet by the form factor of the bullet's tip.

With faster calibres that shoot sleek bullets with high BC's, the atmospheric effects are less than slow calibres that shoot round nose bullets. A bullet is much less affected at say 100 to 300 yards for hunters, as opposed to the 1,000 yards Benchrest shooters. The typical time of flight for a bullet, out of a 308 Win, over 1,000 yards is about 1.5 seconds and about 0.12 seconds at 100 yards or 12.5 times quicker (not ten times). Another way to look at it is to look at velocity decay. I will illustrate with the same calibre bullet, same bullet weight, same initial velocity at the muzzle, but different BC's for a .308" bullet.

Bullet make	Speer	Speer	Speer
Bullet Type	BTSP	Grand Slam	RN
Bullet Weight	180 gr	180 gr	180 gr
Bullet Length	32.77 mm	29.46 mm	27.94 mm
BC	**0.531**	**0.409**	**0.299**
Distance	Velocity/bullet Drop	Velocity/bullet Drop	Velocity/bullet Drop
@ Muzzle	2,560 fps and 0"	2,560 fps and 0"	2,560 fps and 0"
@ 100 yds.	2,400 fps and 2.7"	2,353 fps and 2.8"	2,280 fps and 2.8"
@ 200 yds.	2,246 fps and 11.5"	2,156 fps and 11.9"	2,017 fps and 12.4"
@ 300 yds.	2,098 fps and 27.3"	1,969 fps and 28.3"	1,774 fps and 30.5"
@ 400 yds.	1,955 fps and 50.6"	1,792 fps and 53.9"	1,554 fps and 60.2"
@ 500 yds.	1,818 fps and 83.2"	1,627 fps and 90.8"	1,360 fps and 103.9"

The velocity decay for the first 100 yards, in respect of the three bullets, are 6.25%, 8.1% and 10.9% respectively. By the time we get to 500 yards, there is a substantial difference in striking velocity. Gravity is another aspect, quite apart from climatic conditions. Gravity causes the bullet to drop towards the earth over time. (Shooting on the moon would show different trajectories.) Again, for hunters, as the distance is shorter, the time duration is less for gravity to take its effect. Bullet drop is negligible up to 100 yards, but beyond 200 yards, bullet drop becomes a material factor to reckon with, as the decay in velocity works together with gravity (9.8 m/sec^2). The effect of gravity on a bullet is constant regardless of its weight, shape or velocity. Thus, for long-range hunting, range estimation becomes critical.

Changes in powder temperature should be seen separately from air temperature. Leaving bullets on the bench in the sun on a hot day will quickly elevate the powder's temperature as copper conducts heat very well. Walking in direct sunlight for hours on a hot summer's day will increase pressure (and velocity) to the point that you might experience sticky bolt lift or even difficult case extraction when hot loads are being used. Many hunters have experienced a different point of impact, by sighting in their rifles in the Highveld of Johannesburg (+5,500 ft.) and go shooting in the Lowveld of Nelspruit area (+800 ft.).

I know of a case, where a load was 100% in Pretoria but proved to be too "hot" for Nelspruit as the bolt would not open without force. That is why the outfitter or the farm owner generally insist that the hunter checks his rifle out again just before the hunt. Also, the scope could have moved whilst in transit, just to mention another obvious variable.

Long-range shooting - When we get out to 1,000 yards and beyond, on a specific day, at different altitudes, air pressure (density of air) can make a noticeable difference to the bullet's trajectory. If the shooter happens to know this, it could increase his accuracy at range. Having a Kestrel measuring instrument that can measure the instantaneous pressure is the best solution. The **Kestrel 5500 Weather Meter** provides the shooter with, among other things, a "density altitude" reading. Its features are:

- Altitude (Barometric)
- Barometric Pressure
- Compass Direction
- Crosswind
- Density Altitude
- Dew Point Temperature
- Headwind/Tailwind
- Heat Stress Index
- Relative Humidity
- Station Pressure (Absolute Pressure)
- Temperature
- Wet Bulb Temperature
- Wind Chill
- Wind Speed/Air Speed

Kestrel 5500 Weather Meter

What Is Density Altitude? Density altitude is "pressure altitude" corrected for non-standard temperature. As temperature and altitude increase, air density decreases. As already mentioned, atmospheric conditions – the barometric pressure, altitude, temperature and humidity all influence air density.

Putting it differently - The density altitude is the altitude relative to standard atmospheric conditions at which the air density would be equal to the indicated air density at the place of observation. In other words, the density altitude is the air density given as a height above mean sea level. The density altitude can also be considered to be the pressure altitude adjusted for non-standard temperature.

Barometric pressure is station pressure adjusted to sea level. **Station pressure** or absolute pressure is the air pressure right where it is measured. Air pressure is typically measured in inches of mercury (in Hg) and is the weight of the earth's atmosphere pushing down on us.

Because this estimate is important for aviation and weather forecasting, the U.S. Army created a standard atmosphere model **Standard Metro model**, which it used until the early 1960s and is still employed by the shooting industry to this day, because of the wealth of data that has been generated over the last 50 plus years of use.

Example: Consider a 168 grain .308 calibre bullet @ 2,629 fps sighted in at say 200 yards, shooting with a scope mounted 1.5" above the centre of the bore, and shooting at 500 yards - Calculations were done with the **Strelok Ballistic Calculator**: -

- On an 85-degree F (29.4°C) day and 100 feet above sea level, the drop at 500 yards is 48.7".
- On a 35-degree F (1.7°C) day the drop is 55.67".
- The same 85-degree day, but at 6,100 feet above sea level, the drop at 500 yards is 47.95", only 3/4" less.
- At 35 degrees F, the drop is 55.0", only 2/3" less.

As can be seen, temperature is by far a larger contributor than is altitude. Density Altitude is what affects the atmospheric drag on the bullet, and that is a combination of altitude and temperature. Temperature is the bigger of the two as illustrated. Once past 500 yards, you should start paying attention to atmospheric conditions and recalculate your ballistic outcomes.

The 10th Mountain Division is a light infantry division in the **United States Army** based at **Fort Drum, New York**. Designated as a mountain warfare unit, the division is the only one of its size in the U.S. military to receive intense specialized training for fighting in mountainous and arctic conditions. In February 2015, 2nd Brigade Combat Team, 300 troops of the 10th Mountain Division were deployed to Afghanistan as part of the Resolute Support Mission in the Post ISAF phase of the war between late summer and early fall 2015 along with about 1,000 troops from the 3rd Brigade Combat Team.

Editor's Note:
In the November/December 2020 issue of African Outfitter, the author will illustrate some of the factors that affect bullet drag by sharing some interesting observations during the deployment of a team from America's 10th Mountain Division in Afghanistan with our readers.

Read more about the Afghanistan war in the Nov/Dec 2020 issue of African Outfitter.

M110 semi-automatic sniper system. It shoots a 7.62x51mm round with an effective firing range of 866 yds.