APPLIED BALLISTICS
THE SCIENCE OF ACCURACY

Gyroscopic (spin) Drift and Coriolis Effect

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Most long range shooters are aware of the effects of gravity, air resistance (drag) and wind on their bullets trajectory. There are many commercial ballistics programs on the market that do a fine job of predicting trajectories which only account for gravity, drag and wind. Gravity drag and wind are the major forces acting on a bullet in flight, but they're not the only forces. In this article, I'll explain some of the more subtle forces that influence the path that bullets take.

Gyroscopic drift and Coriolis acceleration is the subject of this article. These effects are commonly misunderstood by many long range shooters for a couple reasons. The first reason is because their effects are small in comparison to other factors. Secondly, the theory behind them can be difficult to understand. Big or small, understood or not, these influences affect every trajectory in a predictable way. I'll try to explain where these forces come from, what practical consequence they have on your trajectories, and what you can do to predict and correct for them.

Gyroscopic (spin) Drift

First, a quick fact about spinning objects…

Picture a spinning object like a bullet or a top. The spinning thing has a 'spin axis', about which it's spinning. If you try to disturb the spin axis by applying a force, or a torque to that axis, the spinning object reacts in a strange way. Rather than simply moving in the direction that you pushed it, the spin axis reacts by moving 90 degrees from the applied force, in the direction of rotation. In other words, if you have a top spinning clockwise on the table in front of you, and you push the top of it's stem straight away from you, the stems first reaction is to jump to the right. After the initial reaction, it will precess into its new equilibrium. Now, on to bullets.

Consider a bullet fired at some angle on a long range trajectory. The bullet starts out with its spin axis aligned with its velocity vector. As the trajectory progresses, gravity accelerates the bullet down, introducing a component of velocity toward the ground. The bullet reacts like a spiraling football on a long pass, by 'weather-vaning' it's nose to follow the velocity vector, which is a nose-down torque. The price you pay for torqueing the axis of rotation is that the nose points slightly to the right as it 'traces' to follow the velocity vector. This slight nose right flight results in a lateral drift known as 'gyroscopic drift'.

Having a left or right twist will change the direction of gyroscopic drift. Bullets fired from right twist barrels drift to the right, and vise versa by the same amount, typically 8-9 inches at1000 yards for small arms trajectories. Gyroscopic drift is an interaction of the bullets mass and aerodynamics with the atmosphere that it's flying in. Gyroscopic drift depends on the properties (density) of the atmosphere, but has nothing to do with the earth's rotation.

Coriolis Acceleration

Accelerations due to the Coriolis Effect are caused by the fact that the earth is spinning, and are dependant on where you are on the planet, and which direction you're firing. It breaks down like this:

There are horizontal and vertical components to Coriolis acceleration.

The Horizontal component depends on your latitude, which is how far you are above or below the equator. Maximum horizontal effect is at the poles, zero at the equator. The horizontal component doesn't depend on which direction you shoot. Typical horizontal Coriolis drift for a small arms trajectory fired near 45 degrees North Latitude is about 2.5-3.0 inches to the right at 1000 yards.

The Vertical component of the Coriolis effect depends on what direction you shoot, as well as where you are on the planet. Firing due North or South results in zero vertical deflection, firing East causes you to hit high, West causes you to hit low. The vertical component is at a maximum at the equator, and goes to zero at the poles. Typical vertical deflection at 45 degrees North (or South) latitude for a 1000 yard trajectory is the same as for the horizontal component: +2.5 to 3.0 inches (shooting east), or -2.5 to 3.0 inches when shooting west.

What are the consequences?

So those are the facts. But what does all this mean, practically, to long range target shooters? The answer lies in understanding the following: The effects of gyroscopic drift and Coriolis drift are independent, and cumulative. In other words, they add, and you can make them add up in more or less favorable ways.

For example (typical 1000 yard small arms trajectory), if you always shoot in the northern hemisphere where the horizontal drift is always to the right, and you have a right twist barrel as most of us do, then your bullet will drift to the right approximately 9" due to gyroscopic drift, and an additional 2.5" due to Coriolis, resulting in 11.5" right drift, even in zero crosswind. However, if you had a left twist barrel in the northern hemisphere, gyro drift and Coriolis drift would partially offset each other, resulting in only 6.5" drift to the right. What's that mean practically, to competitive target shooters? I can think of only one answer:

Long range prone shooters (perhaps some BR shooters as well) like to set a "zero wind" value on their sights as a reference point. If this zero wind setting is determined for a 100 yard zero, then it will be wrong for longer ranges. The difference between the left and right twist barrel means that the long range, no wind zero will be off by either 1/2 or 1 MOA due to the combined effects of gyroscopic and Coriolis drift. Considering this, it would be more beneficial to have a left twist barrel. Having said that, I wouldn't order a special made barrel for that reason. It might cost more, and I'm more comfortable letting the barrel makers do what they're more comfortable with. I'd do the math and adjust my long range zero wind setting before I'd special order a left twist barrel.

Furthermore...

As the most precise shooters on the planet, BR shooters are allowed sighters, before they begin their record shots. Allowing sighters gives BR shooters the luxury of 'dialing out' all these small components of deflection that are different on different ranges, etc. So BR shooters don’t really have to understand, or care about the effects. However, long range hunters and snipers are people who have more of an interest in having the very first shot hit the point of aim (they require precision AND accuracy). Therefore, I think that those people may be more interested in understanding and correcting for such effects as gyroscopic drift and Coreolis drift. Of course, it may not be worth it to carry around the flushing toilet that’s required to measure the strength of the Coriolis effect that day.

Regardless of how the effects add or subtract from each other, these effects are 'knowable', and therefore correctable by anyone who understands and accounts for them. To my knowledge, there are no commercial ballistics programs (affordable to the average shooter) that calculate gyroscopic drift. It depends on a number of aerodynamic coefficients that are not easy to calculate. However, the good news is that gyroscopic drift is relatively constant for a wide range of small arms calibers and flat fire (less than 10 degrees) trajectories. You can count on no more than 10 to 12 inches at 1000 yards.

As for Coriolis acceleration, you can look that up in physics books, or ballistics books like Modern Exterior Ballistics.

I have an idea for how one might alleviate some of the hassle caused by gyroscopic and Coriolis drift. Since most of us live in the Northern Hemisphere, and most of us use right twist barrels, we suffer the unfortunate consequence that the gyroscopic drift, and the lateral component of the Coriolis drift compound each other. Most of us probably have at least 1 MOA of drift to deal with on our sights between short and long range wind zeros. I haven't done the math on this yet, but it seems that you ought to be able to figure out the correct degree of 'cant' at which to mount your scope, that will counteract the effects of drift. The angle should be very small, as to be indiscernible by the shooter. I doubt you would get it to work out perfectly for all ranges, but you might be able to get it 'good enough'. This practice can also be applied to iron sights by mounting your level at a small angle to level. Some day I'll have to do the math on that one.

If you're interested in actually calculating Coriolis drift, check out my book: *"Applied Ballistics for Long Range Shooting"* which has worked examples of these calculations.