Shot-to-Shot Variation in Muzzle Velocity (MV) and Ballistic Coefficient (BC)

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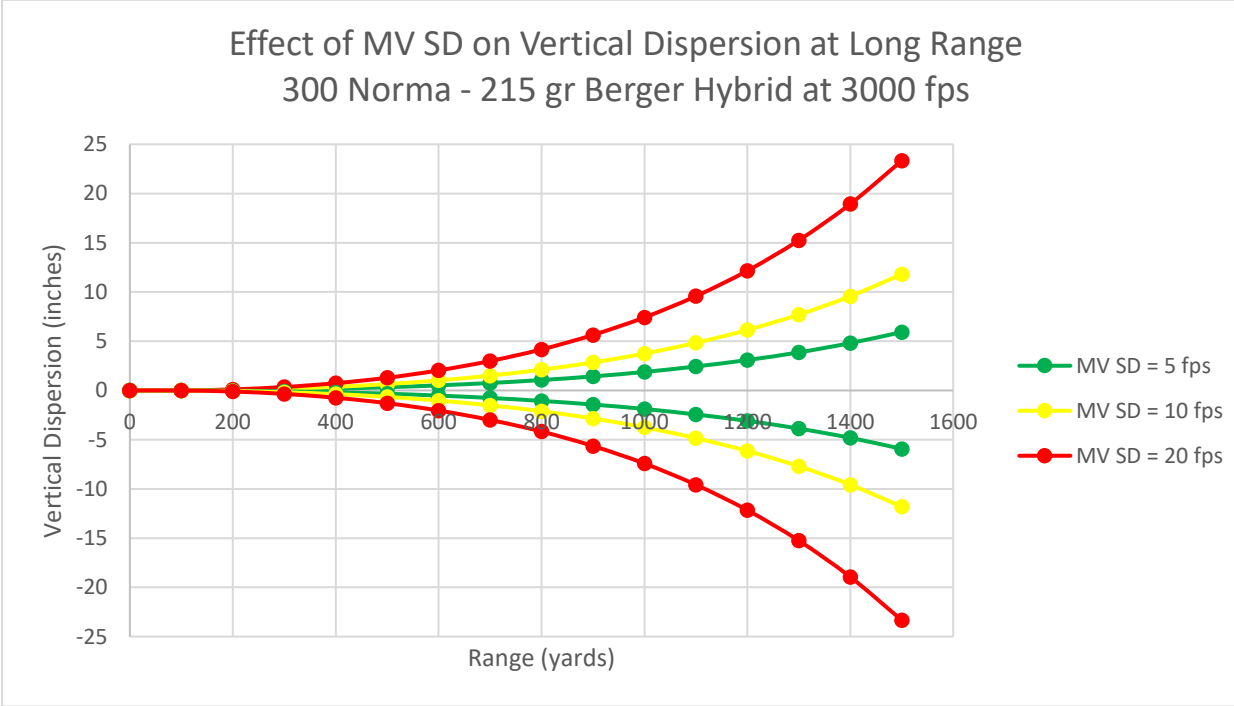
Most long range shooters are aware that they have variation in Muzzle Velocity (MV) around the average. This can be measured with a chronograph, and the goal is to minimize the variation so your shot group doesn't grow too tall at long range (fast shots hit higher than slow shots). The data in Figure 1 is an example of how your vertical dispersion will grow at long range for 3 different levels of Standard Deviation (SD) in MV[i].

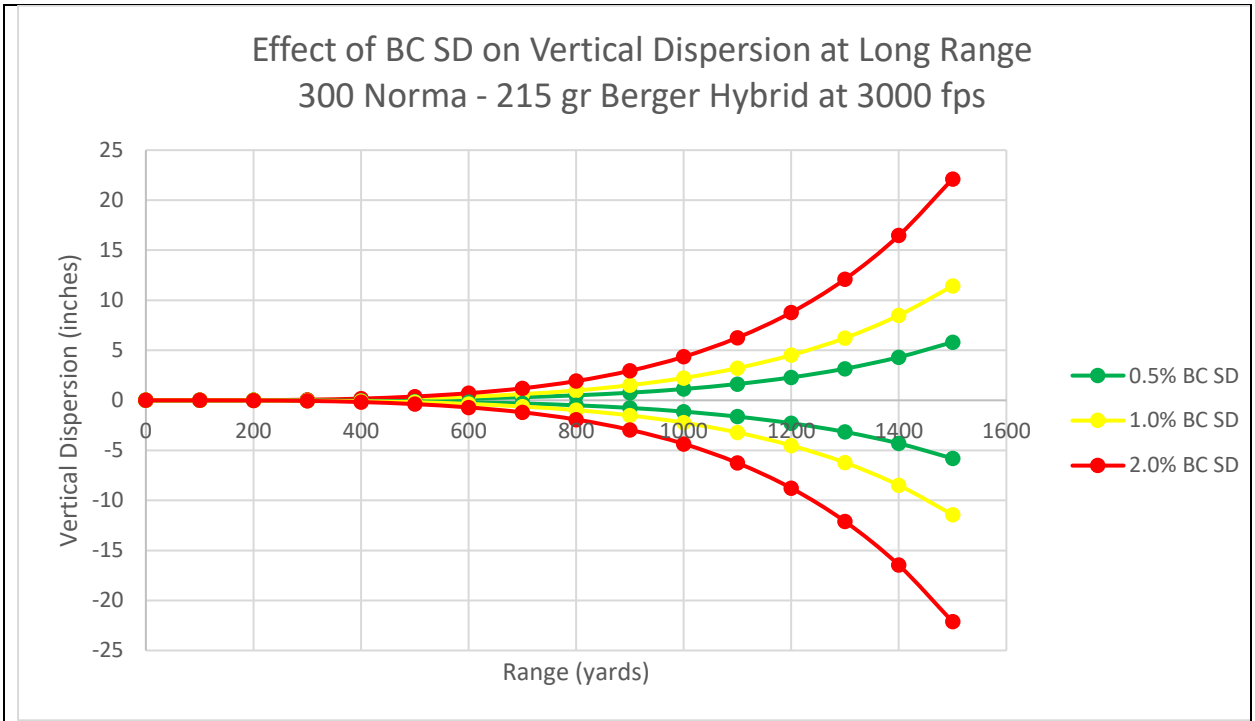


Range (yards)	SD = 5 fps	SD = 10 fps	SD = 20 fps
100	0	0	0
200	0.04	0.1	0.22
300	0.18	0.36	0.7
400	0.38	0.74	1.48
500	0.66	1.3	2.58
600	1.04	2.06	4.08
700	1.52	3.02	5.98
800	2.12	4.22	8.34
900	2.86	5.7	11.28
1000	3.76	7.5	14.84
1100	4.88	9.68	19.16
1200	6.18	12.3	24.32
1300	7.74	15.4	30.5
1400	9.62	19.14	37.88
1500	11.86	23.6	46.66

Figure 1. How MV SD causes vertical dispersion at long range.

MV causing vertical dispersion at long range is common knowledge, but what about BC variation from shot-to-shot? Most shooters don't have a means to measure the BC of each shot, and don't know what the SD of the BC is for their ammo.

Using Doppler Radar, it's possible to measure the BC of each individual shot, and determine the SD of the BC, and the vertical dispersion that results at long range. This data is shown below in Figure 2.



Range (yards)	BC SD = 0.5%	BC SD = 1.0%	BC SD = 2.0%
100	0	0	0
200	0	0	0.02
300	0.02	0.06	0.12
400	0.08	0.18	0.34
500	0.2	0.38	0.76
600	0.38	0.72	1.42
700	0.62	1.24	2.4
800	1	1.96	3.84
900	1.52	3.02	5.9
1000	2.26	4.46	8.7
1100	3.26	6.44	12.52
1200	4.58	9.04	17.56
1300	6.32	12.46	24.22
1400	8.62	16.98	32.94
1500	11.62	22.86	44.26

Figure 2. SD of BC causes vertical dispersion at long range as well.

We can make a couple observations about the data in the previous two Figures:

- MV SD causes more vertical dispersion beginning at shorter range, whereas the effect of BC variation isn't much of a factor until longer range, but then grows more rapidly.
- A MV SD of 5 fps has a comparable effect on vertical dispersion as 0.5% SD in BC.
- A MV SD of 10 fps has a comparable effect on vertical dispersion as 1.0% SD in BC.
- A MV SD of 20 fps has a comparable effect on vertical dispersion as 2.0% SD in BC.

Thru many Doppler Radar tests, we've found that BC SD's can be in the 0.4%-0.6% range for very high quality bullets, and/or bullets that have been pointed and/or meplat trimmed for uniformity. Typical bullets have BC SD's around 0.8%-1.2%. On occasion, some bullets exhibit excessively high BC SD's in the range of 1.5%-2%+. These are typically the very long bullets, or bullets with stability issues.

Figure 3. Applied Ballistics crew operating the doppler radar to measure MV and BC.

In the radar data output below you can see how the BC can be different on every shot. In this particular group, the MV SD is 5 fps, which is very good. The SD in BC is measured to be 0.00111. This equates to: 0.00111/0.368 = 0.3% which is also very good. In fact, the Berger 0.308 cal 215 grain Hybrid bullets were pointed in this test, which increases the average BC, as well as the consistency of the BC. This is highly consistent ammo that will certainly minimize vertical dispersion at long range!

Caliber:	0.308	Inches
Weight:	215	grains
Brand:	Berger	
Model:	Hybrid	
Twist Rate:	8	inches/turn
Temperature:	91	F
Pressure:	27.02	inHg
Humidity:	39	%
Notes:	MRAD 4	

Shot	V_0	V_{100}	V_{1200}	BC_{0-100}	$BC_{100-1200}$	BC_{0-1200}	TOF_{1200}
1	2987	2874	1784	0.366	0.366	0.366	1.5623
2	3000	2888	1801	0.37	0.368	0.368	1.5504
3	2995	2884	1801	0.371	0.37	0.37	1.5516
4	3001	2887	1798	0.364	0.367	0.367	1.5521
5	2999	2887	1802	0.37	0.369	0.369	1.5507
6	2997	2885	1801	0.367	0.369	0.369	1.552
7	3000	2888	1799	0.367	0.367	0.368	1.5517
8	2993	2880	1793	0.366	0.367	0.367	1.5568
9	2991	2878	1794	0.369	0.368	0.368	1.5569
10	2990	2879	1795	0.374	0.368	0.368	1.5563
----------Summary----------							
Average:	2995	2883	1797	0.369	0.368	0.368	1.5541
High:	3001	2888	1802	0.374	0.37	0.37	1.5623
Low:	2987	2874	1784	0.364	0.366	0.366	1.5504
ES:	14	14	18	0.009	0.004	0.004	0.01194
SD:	5	5	6	0.00276	0.00111	0.00111	0.003839

Figure 4. Applied Ballistics Radar data showing Average, ES, and SD of MV and BC at various ranges.

[i] Standard Deviation (SD) and Extreme Spread (ES) are related as follows: 95% of shots will be within +/-2 Standard Deviations of the average. So for example, if the average MV is 3000 fps, and the SD is 10 fps, 95% of shots (that's 19/20) will be between 2980 fps and 3020 fps, and ES of 40 fps. In other words, ES is typically 4 times the SD for a 20 shot group.