Effect of Temperature on Home Run Production

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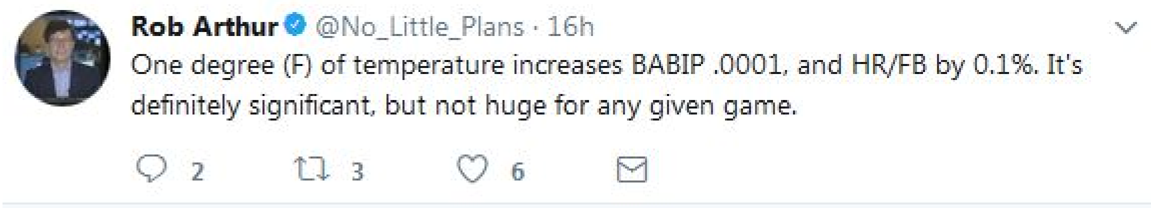
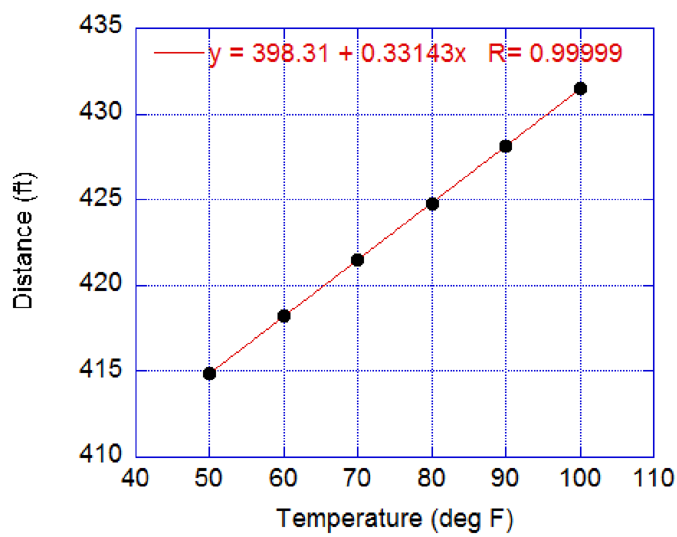
In a recent tweet, Rob Arthur estimated that a 1-deg change in temperature changes home runs per fly ball (HR/FB) by 0.1% (see below). Presumably this result came from some kind of statistical analysis, although I do not know the details. In this brief note, I present a more physics-based analysis. As we shall see, I arrive at a similar result.

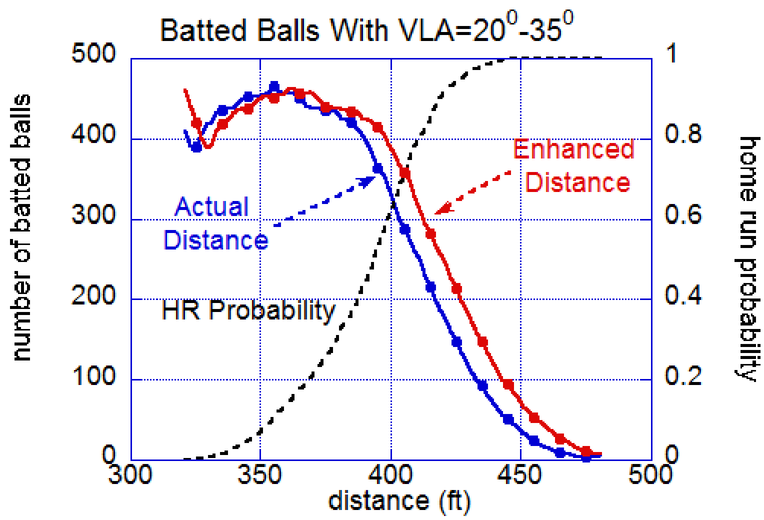


The analysis consists of two distinct parts. First I use my well-developed model of baseball trajectories, my "Trajectory Calculator" (see http://baseball.physics.illinois.edu/TrajectoryCalculator-new-3D.xlsx), to compute how a 1-deg change in temperature the distance of a fly ball hit with a typical home run trajectory, with exit velocity 103 mph and launch angle 28^0. The results are show in the figure below:



The calculation shows that over a range of temperatures 50-100 degrees, the distance is linear with a slope of 0.33 ft/deg. This has to be a pretty solid result, since it is based on a very careful analysis of fly ball trajectories under very controlled conditions. For details, see my recent article in The Hardball Times: https://www.fangraphs.com/tht/fly-ball-carry-and-the-home-run-surge/.

Next, I use Statcast data from 2015-2017 to look at home run probability versus fly ball distance, for batted balls hit with exit velocities greater than 90 mph and launch angles in the range 20^0-35^0. The result is shown in the plot below:



The dashed curve shows home run probability versus distance, averaged over all MLB stadiums. The blue curve shows the actual distribution of fly ball distances for exit velocities exceeding 90 mph. The actual number of home runs can be found by summing over each bucket of distance the product of number of batted balls and the home run probability. Since the distribution of distances is falling rapidly in just the region where the home run probability is increasing rapidly, it is easy to see that a small change in the distances may have a big effect on the number of home runs. As an example, the red curve shows the result of arbitrarily shifting the distances higher by 8.5 ft. for distance greater than about 400 ft. Using that curve to compute the number of home runs, I find that number increases by about 25%. In the Hardball Times article referred to earlier, it was exactly this technique that I used to estimate how the reduced air drag on a fly ball starting in 2016 resulted in an increase in home run production.

Let's now put it all together. A 1-deg increase in temperature results in distances increasing by 0.33 ft. An increase in distance by 0.33 ft will change the number of home runs by (0.33/8.5)*25%, or just about 1%.

Now let's see how this result squares with Rob's, who found that HR/FB increased by 0.1%. After some back-and-forth over Twitter, I now understand what he means by that. Suppose HR/FB=12.0%, or 0.120. Then Rob finds that a 1 deg change in temperature changes HR/FB by 0.1%, raising it to 12.1%, or 0.121. That means the number of home runs increased by the ratio 0.121/0.120, which is 0.8%. Within roundoff errors, this agrees nearly perfectly with my 1%. So, we agree. All is well in the world.

In the classic book, The Physics of Baseball, by Robert K. Adair, on page 97 of the 3rd (and final) edition, he states that "the probability of hitting a home run increases by about 7 percent for each percent increase in the distance a fly ball travels." Let us take as our generic distance 400 ft, so that a 1% increase means 4 ft. My prediction based on that change of distance would be an increase of (4/8.5)*25%, or about 12% in home run production, to be compared with Adair's 7%. So Adair got it wrong by nearly a factor of two. But that is not meant as a severe criticism. After all, he arrived at his result without the benefit of the voluminous amount of data that we now have and still got the number in the right ballpark, so to speak, as he did with so many other things in his book.