The Effect of the Marine Layer on Fly Balls

by David Kagan and Chris Mitchell

It is simply baseball lore. Garrett Anderson warned Torii Hunter when he joined the Angels in 2007. Hunter alerted Albert Pujols when he joined the team in 2012. No doubt, Pujols shared the word with Mike Trout, and given Trout's enthusiasm for all things weather-related, there's no telling how many people he's told. It has been handed down from generation to generation: The marine layer will turn homers into lazy fly balls.

On the face of it, this seems reasonable. The marine layer is the moist, humid, foggy air that wanders from the ocean to West Coast ballparks at night. It sure feels thicker than the warm air of the afternoon – perhaps thick enough to obstruct the flight of a deep fly ball. Torii Hunter estimated the marine layer hacks 15 feet off of fly balls during night games at Angel Stadium.

What is the Marine Layer?

The marine layer is a complex weather phenomenon that only happens along the West Coast. In the United States, weather patterns generally flow from west to east. As air flows eastward across the Pacific Ocean, the water keeps the air cool and moist year-round, resulting in a temperate climate on the West Coast. Further east, the air flows across land that is warmer than the ocean in the summer and cooler in the winter. This explains the hot summers and cold winters in the Midwest and the East.

However, California's temperate climate has a downside: the marine layer. It rears its ugly head from time to time—particularly in June and July—to drag down what would otherwise be warm temperatures. As Mark Twain once remarked, "The coldest winter I ever spent was a summer in San Francisco." Twain was undoubtedly experiencing the marine layer.

As warm air moves across the ocean, the air near the surface of the water is cooled and, therefore, becomes denser. Since denser air sinks, it becomes trapped below the warmer air. The trapped air also becomes more humid due to evaporation from the water. Under the right conditions, fog can form. That fog is the marine layer.

What Does Physics Tell Us?

If you ever took physics or chemistry, you might remember something called the Ideal Gas Law (don't worry, there won't be a quiz). The law tells us that the density of a gas grows with increasing atmospheric pressure and it drops with increasing temperature. In addition, the density of a gas grows as the average mass of the gas molecules increases.

The density of the air will determine the distance of fly balls because less dense air is thinner air. Think Coors Field. A physicist would say something more wonky like, "The higher the air density, the higher the drag force on a ball in flight."

Things are getting complicated now. The marine layer's low temperatures should increase the density of the air and reduce the distance of fly balls. However, the marine layer's high humidity level has the opposite effect. Humidity is the result of water molecules replacing the nitrogen and oxygen molecules in the air. Water molecules are 35 to 45 percent lighter, which reduces the air density. This causes the distance to *increase*. This seems counterintuitive, but it's true: Although it *feels* "thicker," humid air is less dense than dry air.

In Alan Nathan's Hardball Times article, "Going Deep on Goin' Deep," he found that a 10-degree decrease in temperature will shorten the distance of a fly ball by about three feet, while a 50 percent increase in relative humidity will increase the distance by roughly one foot. According to physics, then, there should be little effect due to the marine layer. Both the "temperature effect" and the "humidity effect" are relatively small, and they work to counteract each other.

What Does Statcast Tell Us?

Alan Nathan found that four of the six West Coast parks were below average in terms of average flyball distance. Of these six, only Seattle was not within a standard deviation of the league average. Anaheim is the only West Coast park that falls more than one standard deviation above the average. Clearly, the ball doesn't travel as far on the West Coast, which explains the lack of run scoring out there. But it's less clear whether this is a result of the marine layer cropping up every so often to knock down fly balls.

Our first thought to test for the Marine Layer Effect was to compare the average distance of fly balls hit during the day with those hit at night. In our experience, the marine layer is more likely to occur at night than during the day, as the layer has a tendency to break down in the morning and reassert itself in the late afternoon. The afternoon heat causes air to rise, and it is often replaced by ocean air that drags the marine layer with it.

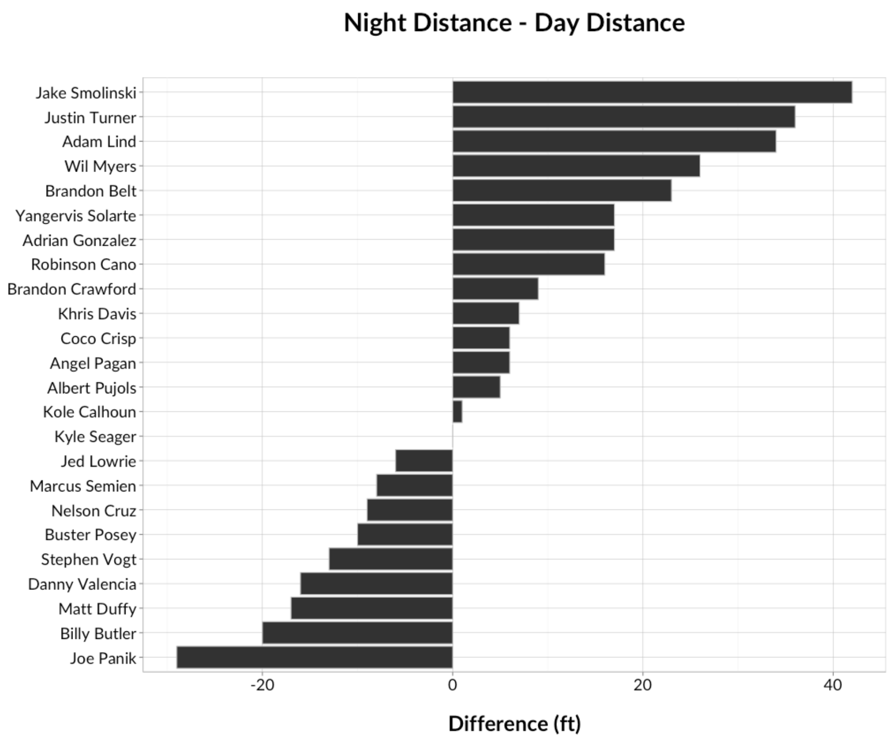
We collected all plate appearances that resulted in a fly ball at each of the six parks, ignoring all events where there was no distance measurement recorded. The results are below.

Flyball Distance by Time of Game, Ballpark						
Day/Night	**SDP**	**LAA**	**LAD**	**OAK**	**SFG**	**SEA**
Night	320’	325’	317’	310’	310’	320’
Day	321’	315’	311’	312’	307’	321’

Three of the six parks have slightly longer flyball distances at night, while three do not. By no means does this debunk the Marine Layer Effect, but the lack of compelling evidence is telling. The ball does not seem to travel any further during the day.

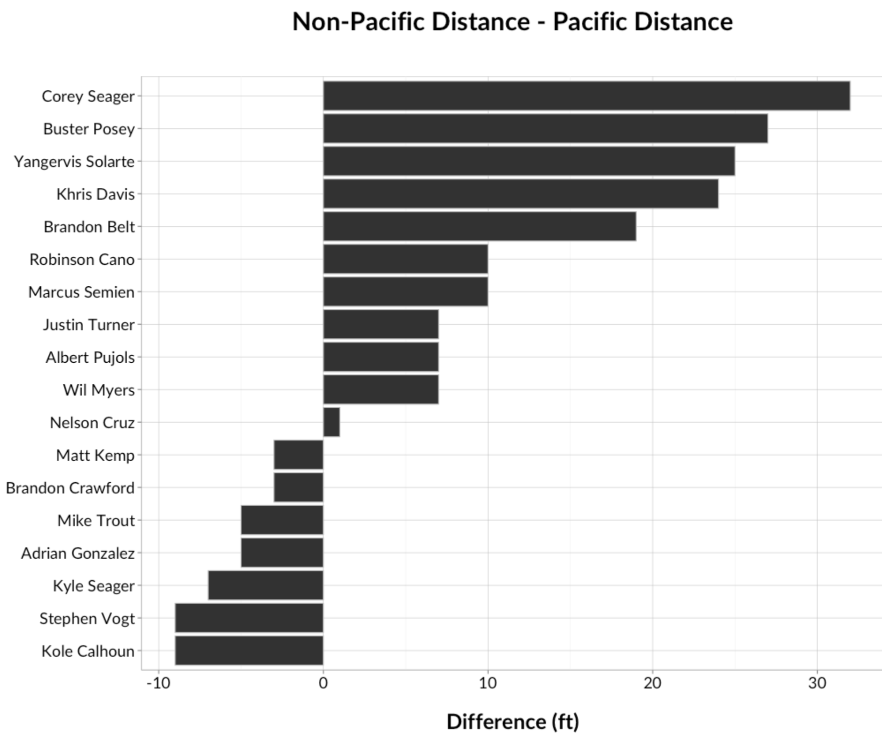
Of course, it is possible factors other than game-time conditions could be at play here. For example, the day sample might be skewed by backups filling in during day games after night games, specifically glove-first backup catchers. This might artificially lower the daytime distance, making the nighttime distances appear too long.

So in addition to slicing the data by team, we looked at individual players that hit at least 10 fly balls during day and night games. The plot below shows the average night distance minus the average day distance for each player.



Players that hit fly balls further at night than during the day have bars above the axis, while players that hit further during the day have bars below the axis. Again, there is no clear evidence that the ball travels further during the day. If anything, these data hint that the reverse may be true.

We also tried splitting the data by ballpark. We selected three power hitters from each of the West Coast teams and compared their average flyball distances at the six coastal parks to their average distance at parks not on the Pacific Coast. Here are the results.



Eleven of the 18 players hit the ball further when removed from their home coast, with some of them doing so by a huge margin. However, it isn't immediately clear whether this is a direct result of the marine layer. This, along with the fact that seven players actually hit the ball further on the West Coast, keeps this one in the inconclusive category.

What Do Weather Data Tell Us?

The methods we have used to this point don't provide conclusive answers to the Marine Layer Effect. They suggest it's somewhere between minimal and nonexistent, but our analyses were admittedly back-of-the-envelope. Carl Sagan once said, "Extraordinary claims require extraordinary evidence." If we are to completely debunk something so ensconced in baseball lore, we'll need to dig deeper.

For a more rigorous analysis, we used the time stamps from Statcast to link to historical weather data from Weather Underground. These weather data are available roughly every 20 to 60 minutes, which is just what we needed, given how quickly the weather can change. On the downside, this fine-grained weather data is only available from airports. We chose the airport closest to the ballpark in each case, but not all ballparks are particularly close to an airport.

There was an additional problem. As Supreme Court Justice Potter Stewart once remarked during a pornography case, "I can't define it, but I know it when I see it." The same holds true for the marine layer. There is no standard threshold for temperature, humidity or anything else at which fog forms, and therefore no purely objective way to define the marine layer. To settle on a definition, we sought help from several weather professionals, including the local TV weatherman. Using their input, we settled on the following definition:

- Temperature ≤ 70 F
- Relative Humidity ≥ 80%
- Conditions: Partly Cloudy (Scattered Clouds), Mostly Cloudy (Broken Clouds), or Overcast

Here are the average fly ball distances from each ballpark split by this definition.

Flyball Distances, By Marine Layer Definition			
Ballpark	**No Marine Layer**	**Marine Layer**	**Difference**
OAK	312'	291'	-21'
SEA	321'	314'	-7'
SD	318'	322'	4'
LAD	315'	321'	7'
SF	307'	316'	9'
LAA	322'	333'	11'

None of these discrepancies seem overly compelling, except for maybe Oakland's. But we can do better than simple raw averages. For each stadium, we built a regression model to predict flyball distance. This allowed us to control for exit speed, vertical (launch) angle, horizontal (spray) angle and pitch speed. By controlling for all of these factors, we can be reasonably sure our "Marine Layer" variable isn't picking up anything that isn't weather-related. Here are the results.

Change in Distance Due To Marine Layer					
Ballpark	**Marine Layer Effect**	**Standard Error (+/-)**	**P-value**	**R-squared**	**Miles from Ballpark**
SD	-6.1'	3.0'	0.04	0.91	3
OAK	-5.6'	3.2'	0.07	0.89	3
SEA	-1.2'	2.3'	0.53	0.96	4

LAA	-1.1’	2.8’	0.69	0.94	7
LAD	-0.1’	2.4’	0.96	0.93	13
SF	2.8’	2.0’	0.16	0.89	14

We have evidence!…Sort of. Our marine layer variable has a negative coefficient in five of the six parks, though only two of them—San Diego and Oakland—are statistically significant (denoted by P-values below 0.10). However, those two parks also happen to be the two that are closest to the airport weather stations. The further the weather reading from the ballpark, the more the signal fades. This suggests the lack of evidence in Seattle, Los Angeles and San Francisco might be a direct result of sub-optimal weather data. Given how much weather can vary across relatively small geographies, we shouldn’t be surprised that anything over a few miles might be enough to sabotage our analysis.

One variable we did not account for was wind. There is no obvious reason to think this skews the results one way more so than the other, but we do know that wind matters a lot. The aforementioned work by Alan Nathan found that a five mph out-blowing wind adds 19 feet to a fly ball’s trajectory. Unfortunately, we couldn’t do much with the wind data from either Weather Underground or Baseball-Reference. Wind just varies too much over time, across geography and even in different parts of the ballpark for that data to be of much use.

Nonetheless, the R-Squared values tell us that we’re accounting for roughly 92 percent of the variance in flyball distance. That’s, like, almost all of it! So it’s unlikely there are any important factors we’re missing aside from better weather data. This analysis seems pretty trustworthy.

Is There Any Evidence of the Marine Layer Effect?

All of this is to say there’s compelling directional evidence of the Marine Layer Effect. The marine layer has a statistically significant effect on flyball distance, and since the data are consistent in the two ballparks with the best weather data, that almost certainly isn’t a fluke. The effect size is around six feet, which isn’t nothing. Six feet could be the difference between an F8 at the warning track and a wall-scraping home run.

But at the same time, six feet isn’t *usually* enough to be a difference-maker. While we’ve confirmed the existence of the marine layer hypothesis, we’ve also formed an idea of just how minimal its effect is. Yes, the Marine Layer Effect is real, but that doesn’t mean it’s large enough to wring our hands over.

There’s a good chance you saw the headlines last year stating “Bacon is Just as Likely to Give you Cancer as Cigarettes.” To everyone’s relief, this wasn’t actually the case, as smoking cigarettes is orders of magnitude more risky than eating bacon every day. The bad headlines stemmed from the finding that both bacon and cigarettes certainly increase cancer risk, even though eating bacon only does so ever so slightly. So just as eating bacon every day *definitely slightly* affects cancer risk, the existence of a marine layer *definitely slightly* affects flyball distance.

What Can We Say About the Marine Layer's Effect on Fly Balls?

At the very least, we can say the marine layer shortens flyball distances. We proved as much with our Statcast/weather study. But there is no evidence the Marine Layer Effect is anything more than marginal. Even when using the best data, our analysis estimated it only shortens flyball distances by six feet.

Just how much six feet matters is a bit hard to quantify. We tried using our same models to predict linear weight run values rather than fly ball distance, but didn't have much success. With fly ball distance, we were able to explain most of the variance just by looking at how the ball was hit, making it relatively straightforward to isolate the Marine Layer Effect. With actual baseball outcomes, however, it's a bit more complicated, as there is so much else that comes into play. Defensive positioning, fielder quality and ballpark idiosyncrasies are all near-impossible to quantify. They're also bigger deals than the Marine Layer Effect, which makes it difficult to isolate its effect on run scoring. We also tried comparing runs per game and home runs per plate appearance in games where the marine layer was in effect to games where it wasn't, but couldn't find any statistical difference.

It's worth noting that our analyses were not perfect. Ideally, we would have used minute-by-minute weather data taken from the field at every ballpark, but we had to do our best with what we had. It's possible our shoddy radar is only picking up a small, six-foot blip when the actual effect is much larger. We don't know for sure how large the Marine Layer Effect is.

The results from our data-crunching are a bit wishy-washy, but they make sense in the context of physics. The two atmospheric symptoms of a marine layer are a lower temperature and a higher humidity. We know both of these symptoms have an effect on flyball distances, but we also know those effects are relatively small. And perhaps more importantly, we know they work in opposite directions. The cold air is dense, but the humidity drags down that density. That suggests a minimal effect, which is exactly what we found.

There's common-sense, anecdotal evidence against the Marine Layer Effect, as well. In Colorado, the thin air creates joy among hitters. Lazy fly balls become homers, while pitchers complain their breaking pitches remain stubbornly straight. On the West Coast, hitters complain they lose homers to the marine layer, yet you never hear that West Coast curveballs snap with extra bite. This disconnect is yet another strike against the Marine Layer Effect.

Every time a ball doesn't travel as far as the fans, players or coaches would have liked, they blame the marine layer. That's human nature. We all like to blame our shortcomings on external factors. Their blame isn't necessarily misplaced, either, as our analysis tells us the marine layer knocks six feet or so off of the average fly ball.

Surely, that's enough to turn the occasional home run into an out. But the claim that the occasional presence of a marine layer explains low run scoring on the West Coast? That seems to be—if you'll pardon the pun—a bunch of hot air.igh.

References & Resources

- Statcast data from Baseball Savant
- Weather data from Weatherunderground.com
- Special thanks to meteorologists Clay Davenport, National Oceanic and Atmospheric Administration (NOAA); Kris Kuyper, Chief Meteorologist, Action News Now; Shane Mayor, Professor of Geosciences, California State University Chico.
- Alan Nathan, The Hardball Times, "Going Deep on Goin' Deep," *hardballtimes.com/going-deep-on-goin-deep*
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