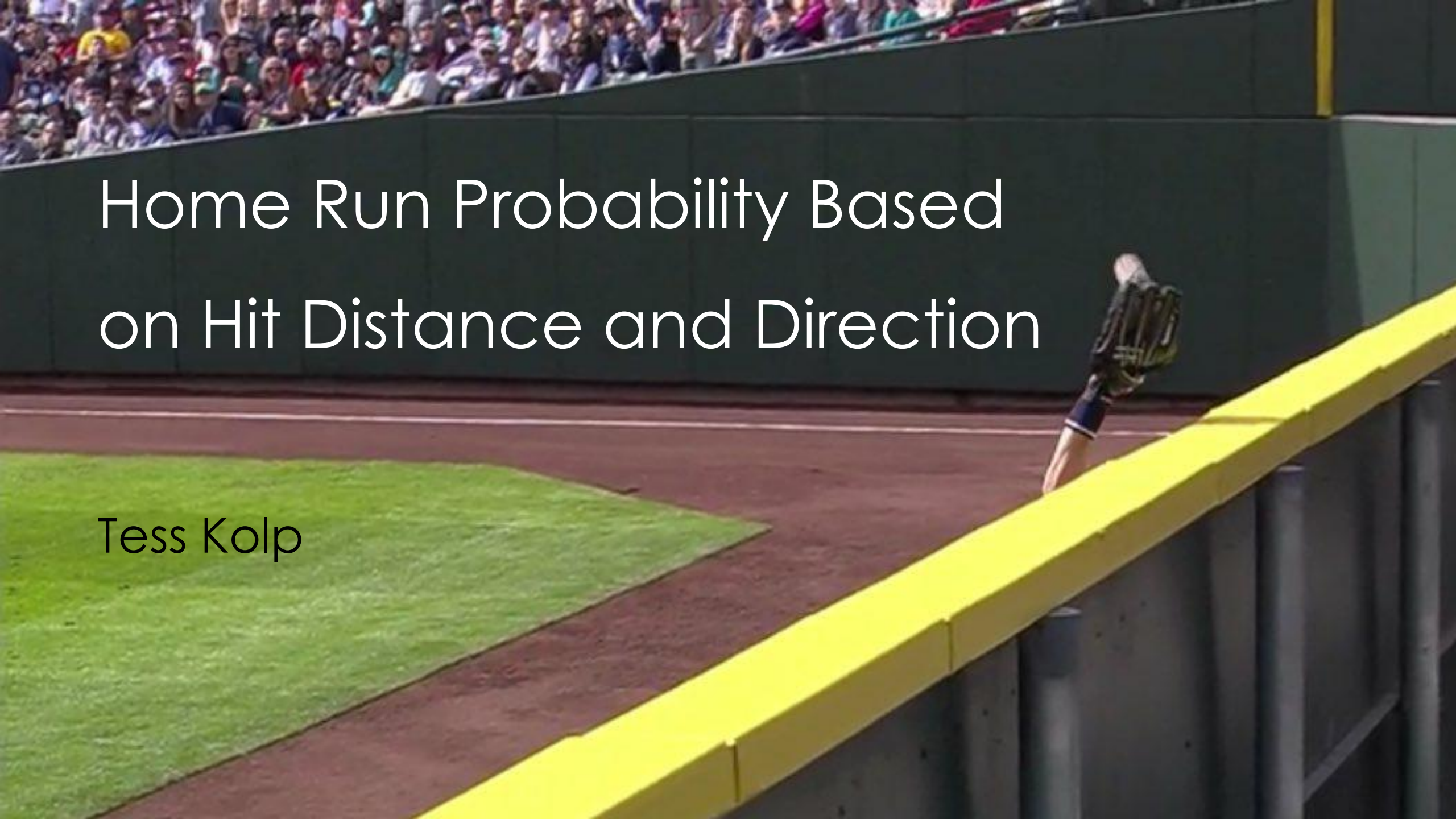


Home Run Probability Based on Hit Distance and Direction

Tess Kolp

BACKGROUND

- Hit probability was introduced by Statcast in 2017
- Attempts to answer the question "Based on the **exit velocity** and **launch angle** of the batted ball, how likely was the ball to land for a hit?"

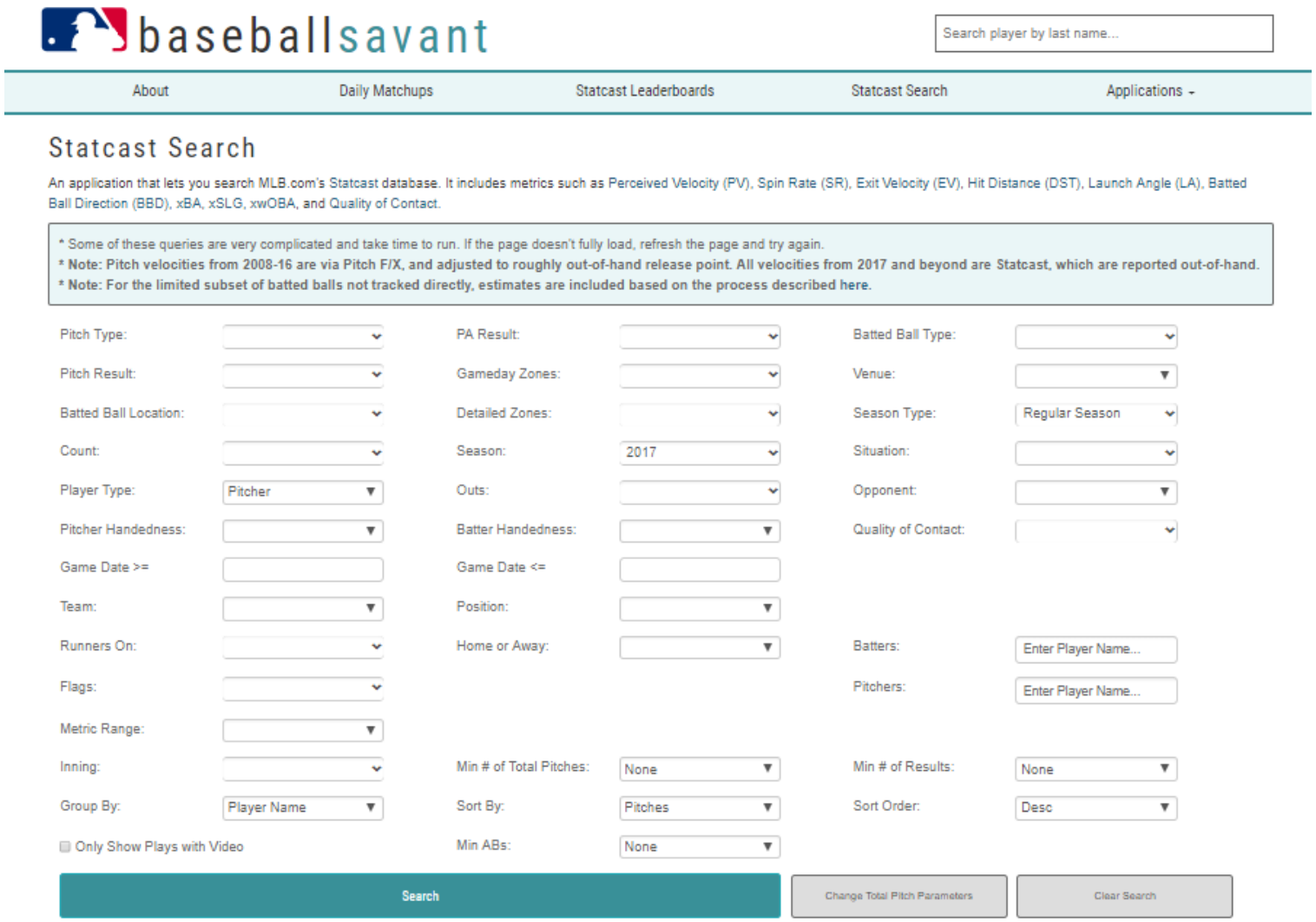
QUESTIONS

- Based on the distance and spray direction of a batted ball, what is the likelihood of it being a home run?
- Who hit long fly outs? (Who was “unlucky”?)
- Who hit home runs that just barely got out? (Who was “lucky”?)
- Where do these long fly outs and short home runs occur?

MODEL SELECTION

- Using the logistic regression model
- A home run is considered a “success” (1)
- Anything else is considered a “failure” (0)

COLLECTING THE DATA



DATA COLLECTED

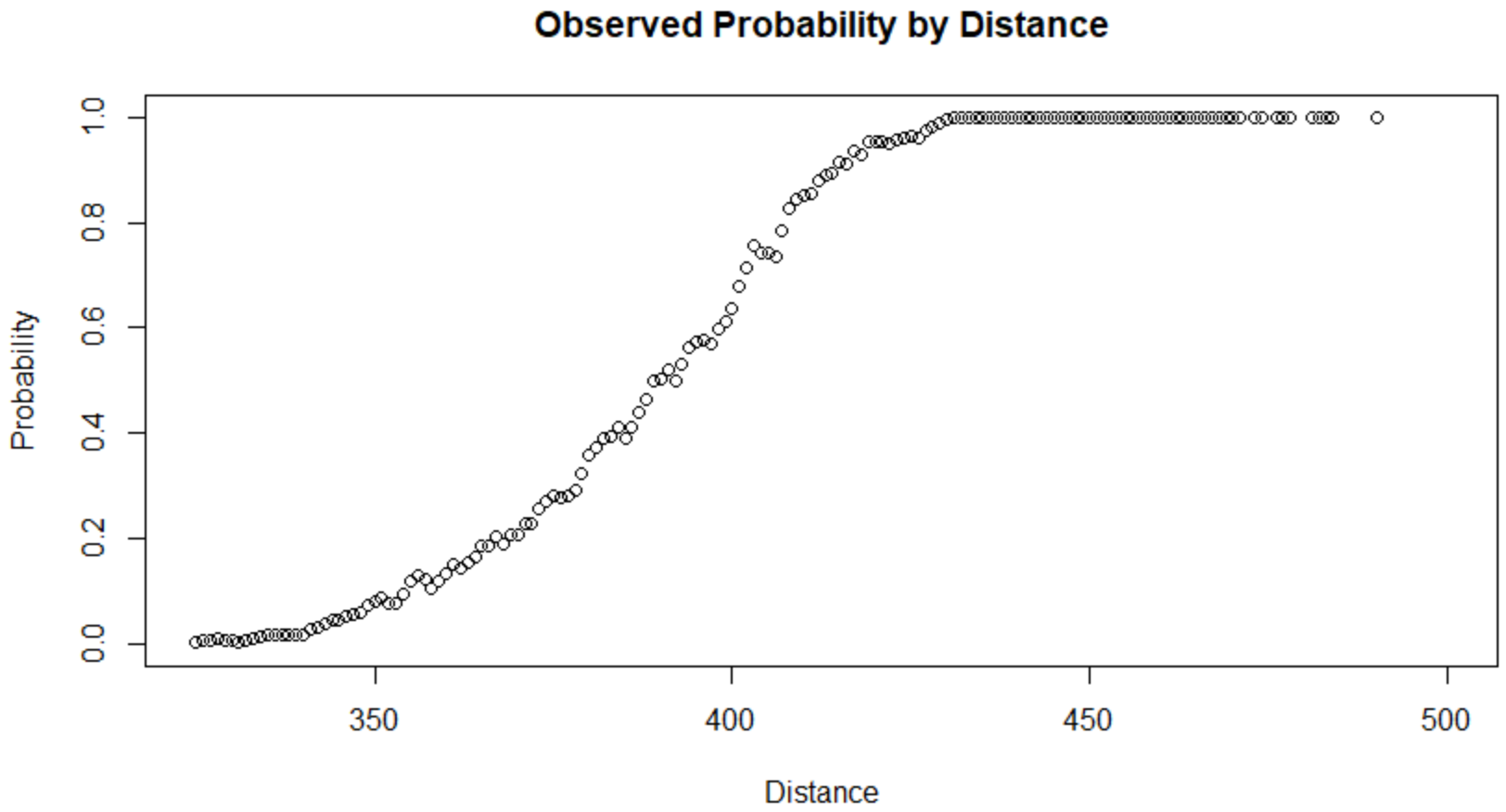
- All batted balls hit greater than 325 feet in 2017 (19,230 data points)

	A	B	C	D	E	F	G	H
1	player_name	events	home_team	hc_x	hc_y	hit_distance_sc	launch_speed	launch_angle
2	Stephen Vogt	field_out	MIN	56.53	84.21	325	96	40.187
3	Michael Brantley	field_error	CLE	56.89	80.06	325	94.2	28.279
4	Kyle Seager	sac_fly	SEA	201.18	83.01	325	97.7	23.263
5	Justin Upton	double	LAA	96.86	64.84	325	90.5	21.191
6	Adrian Gonzalez	field_out	STL	76.69	74.99	325	91.3	20.763
7	Kevin Pillar	field_out	TOR	148.08	63.55	325	92.6	37.228
8	Matt Adams	field_out	ATL	194.87	79.2	325	110.7	17.956
9	Bryce Harper	field_out	WSH	133.81	61.77	325	111	12.13
10	Xander Bogaerts	field_out	BOS	125.83	78.57	325	86.2	30.85
11	Cameron Maybin	field_out	SEA	209.52	88.76	325	96.9	23.524

CREATING MY OWN MODEL

DISTANCE ONLY MODEL

INITIAL OBSERVATIONS



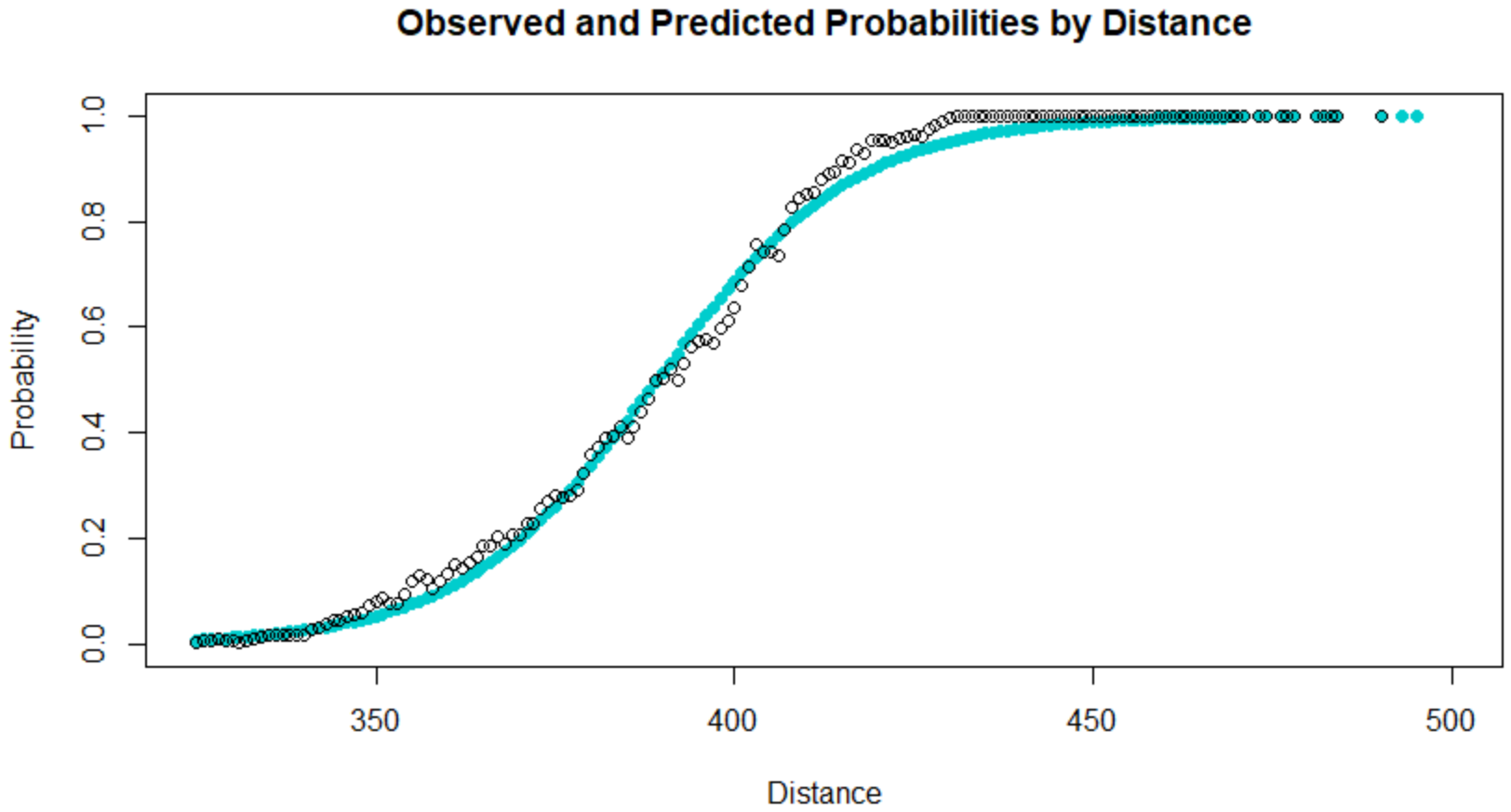
GLM OUTPUT

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-28.301748	0.403003	-70.23	<2e-16 ***
distance	0.072716	0.001055	68.93	<2e-16 ***

$$P(hr\,;\,d) = \frac{e^{-28.30+0.07d}}{1+e^{-28.30+0.07d}}$$

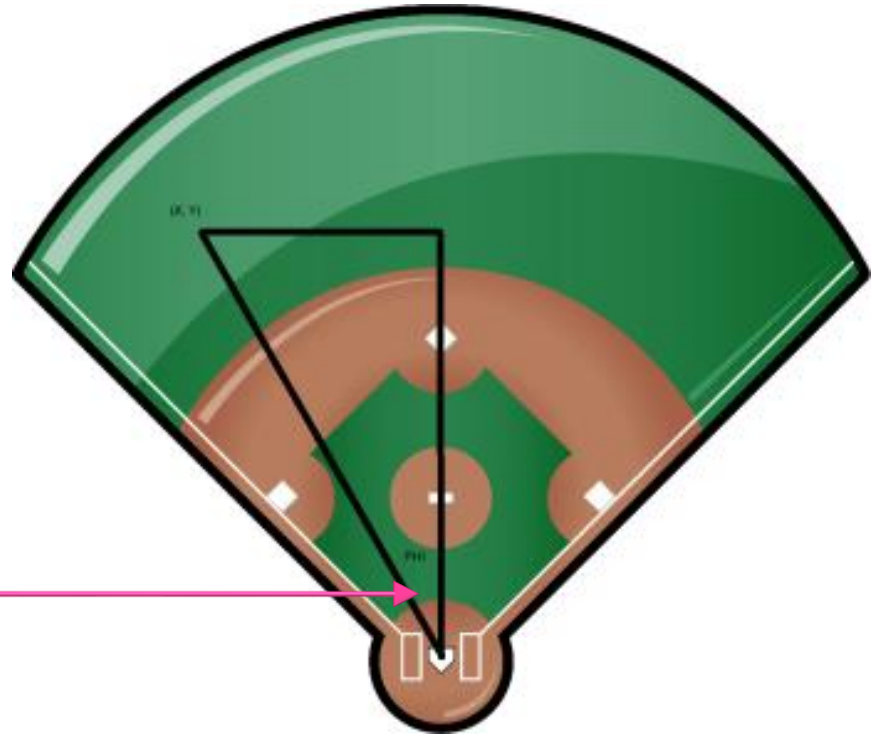
COMPARING MODEL TO OBSERVED PROBABILITIES



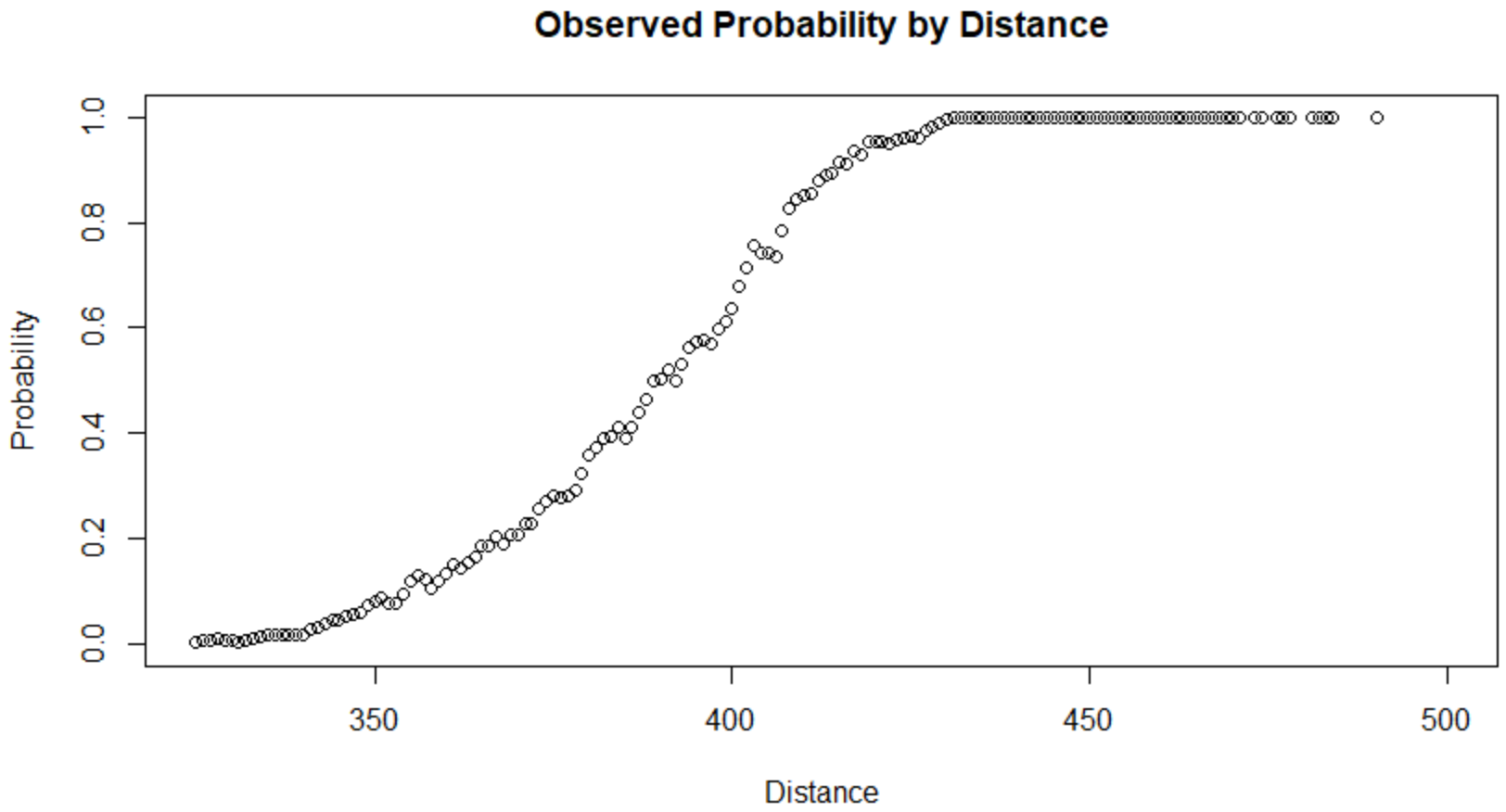
DISTANCE AND DIRECTION MODEL

GETTING ANGLE

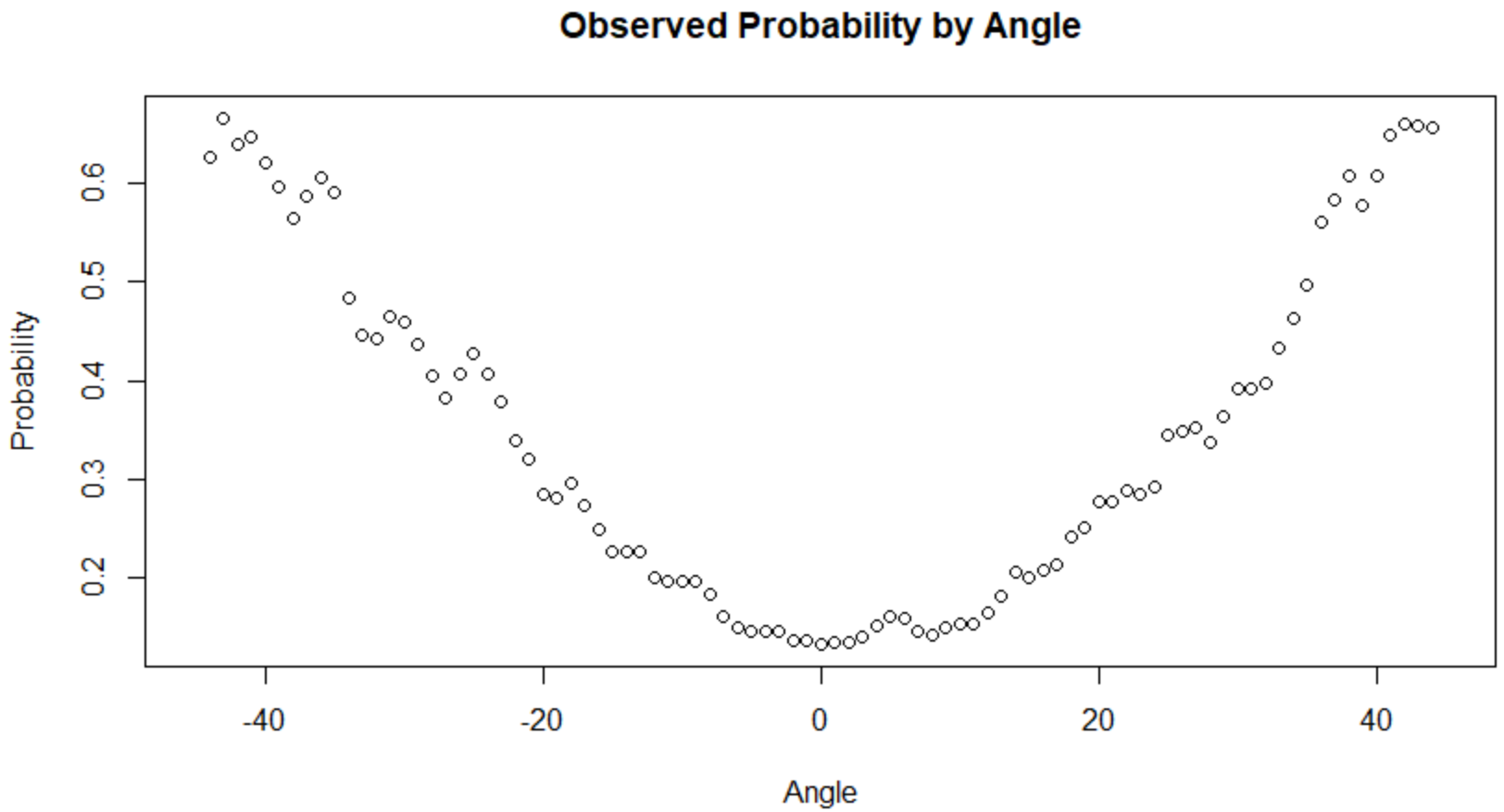
- Transform hc_x and hc_y values so that home plate is (x=0,y=0)
- Convert new x and y coordinates into degrees with arctan



INITIAL OBSERVATIONS



INITIAL OBSERVATIONS



CHECKING ASSUMPTIONS

- **Assumption 1: Observations are independent**
  - Plate appearances are independent

CHECKING ASSUMPTIONS

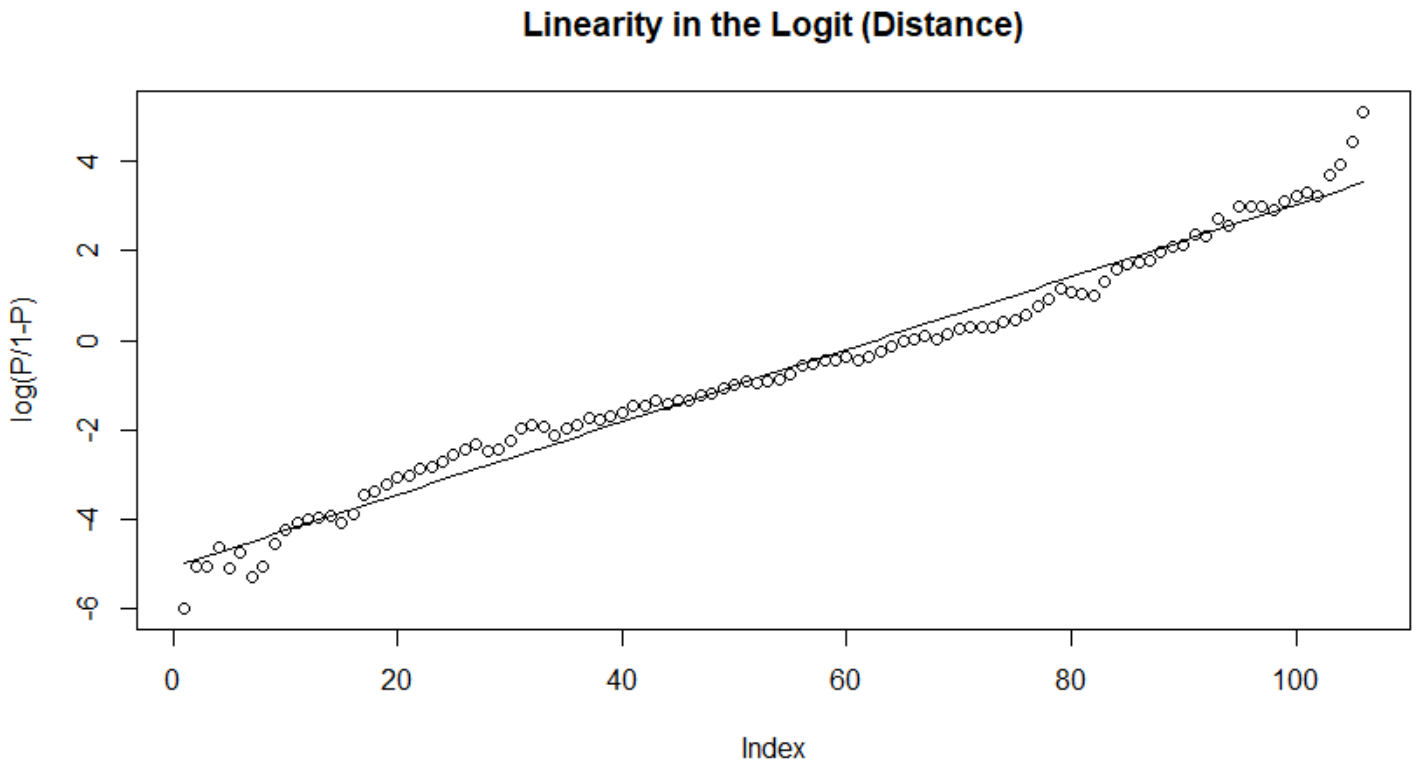
- **Assumption 2: Lack of strongly influential outliers**
  - 19 inside the park home runs left in (short home runs)
  - 8 non home runs 426+ ft. (long non home runs)
    - 4 in Detroit, 1 in Colorado
  - About 0.1% of data
  - Overall distances range from 325 ft. to 495 ft.

- Note: 87 points were removed for having an angle >45 or <-45

CHECKING ASSUMPTIONS

- **Assumption 3: linearity in the logit**

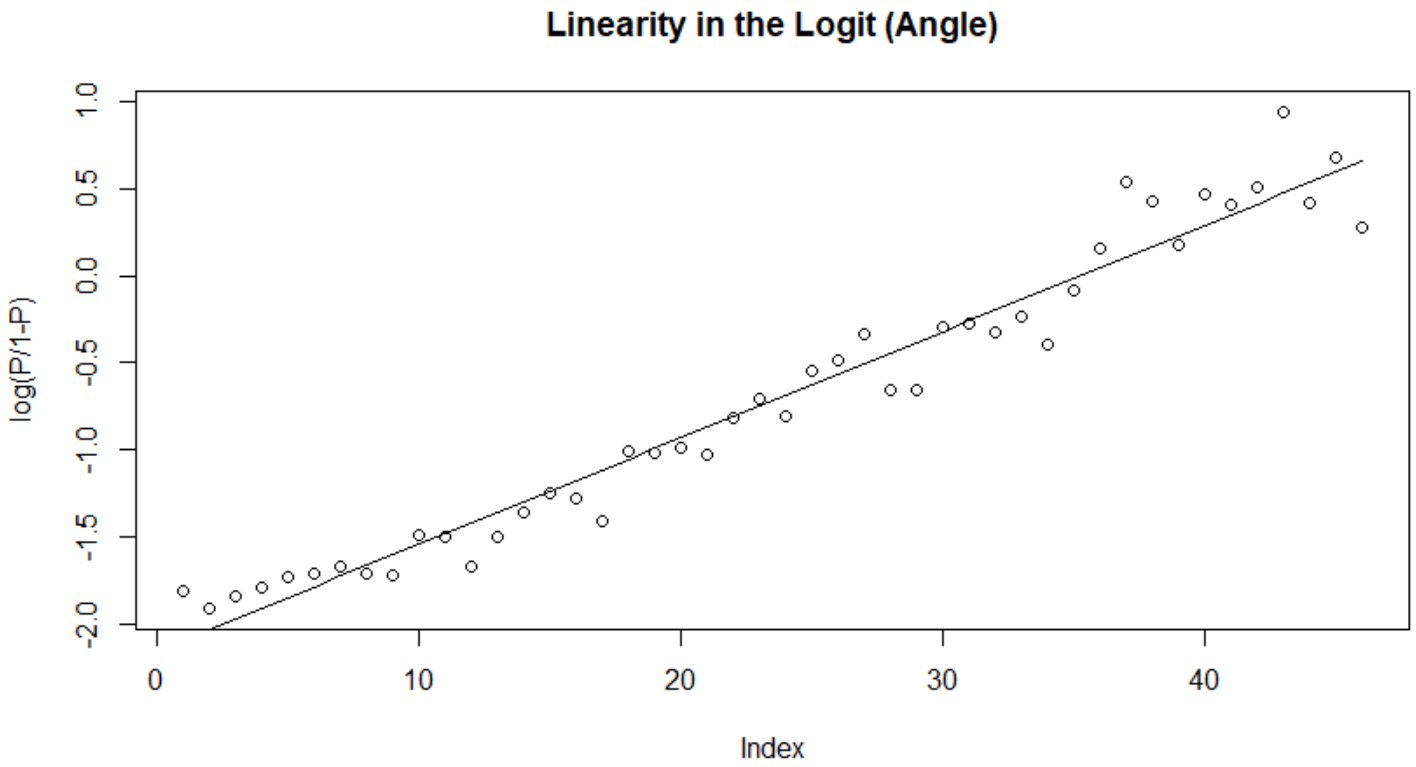
As distance increases, the probability of hitting a home run increases



CHECKING ASSUMPTIONS

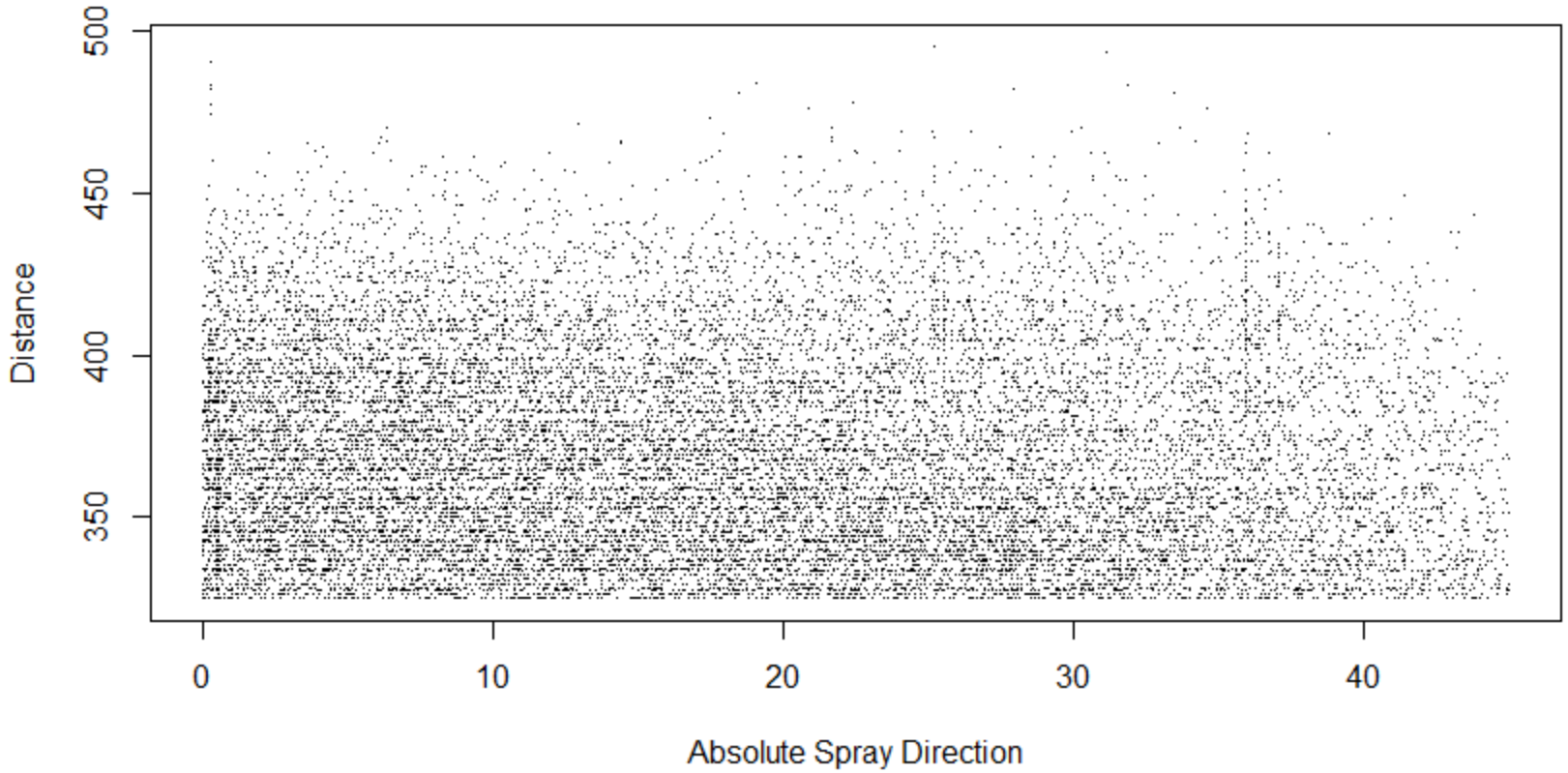
- **Assumption 3: linearity in the logit**

As the absolute value of spray angle increases, the probability of hitting a home run increases



CHECKING ASSUMPTIONS

- **Assumption 4: Little to no multicollinearity**



R^2=0.006

GLM OUTPUT

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-66.304031	1.189777	-55.73	<2e-16 ***
distance	0.158885	0.002870	55.35	<2e-16 ***
ad	0.262412	0.005282	49.68	<2e-16 ***

$$P(hr\,;\,d,a) = \frac{e^{-66.30+0.16d+0.26|a|}}{1+e^{-66.30+0.16d+0.26|a|}}$$

AIC COMPARISON

Distance only model

AIC=13,240

Distance & Direction model

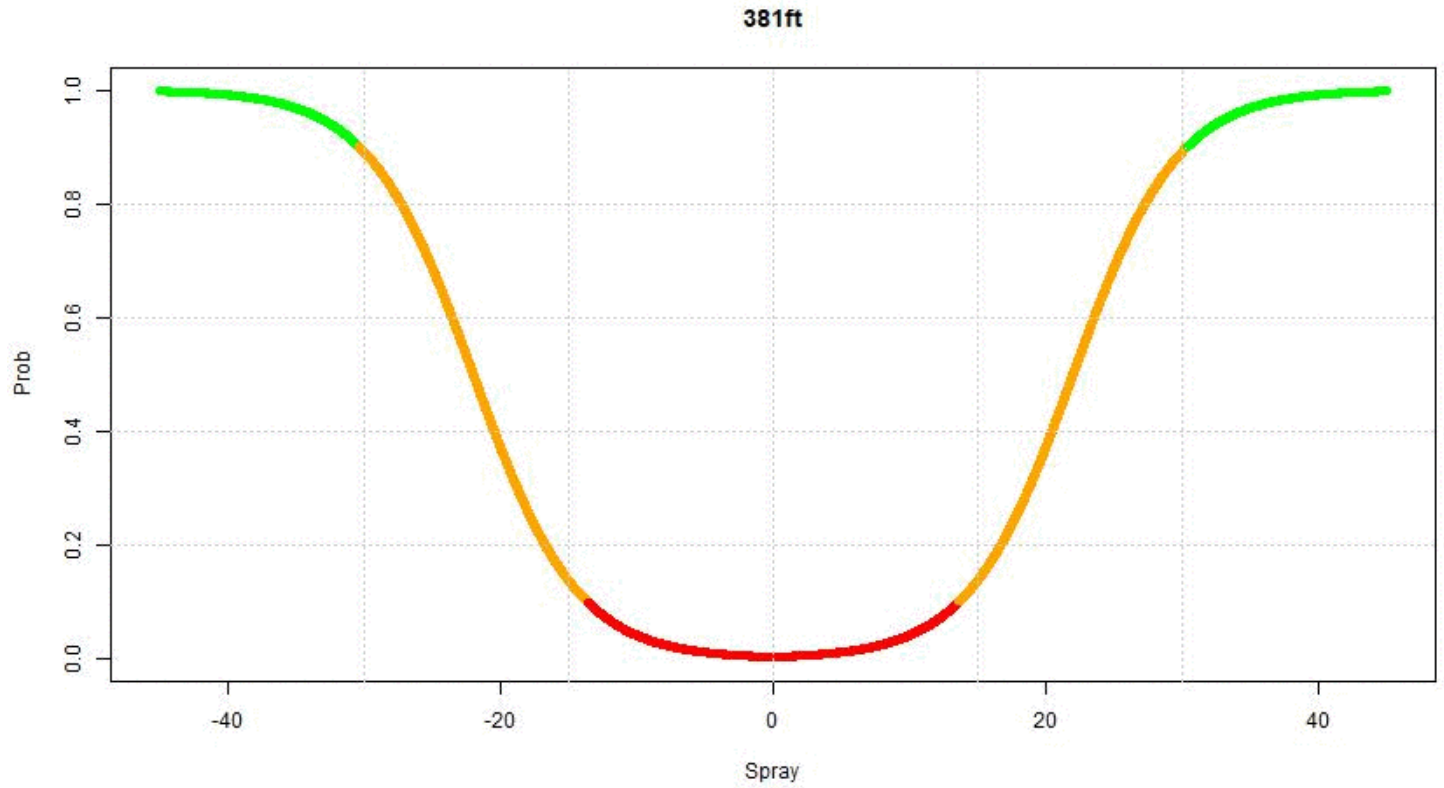
AIC=6,530

(Smaller is better)

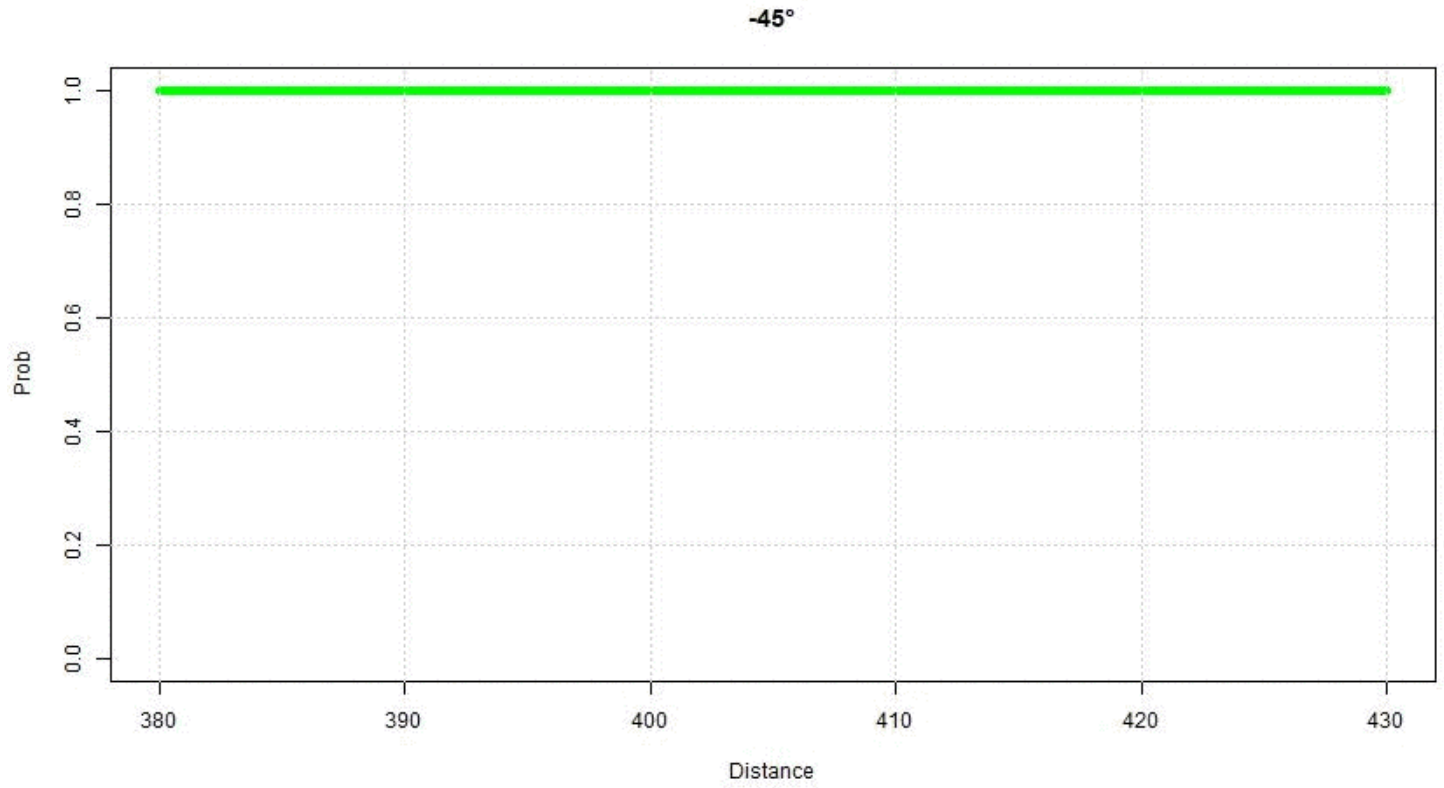
HEAT MAP

	-45	-42	-39	-36	-33	-30	-27	-24	-21	-18	-15	-12	-9	-6	-3	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45
430	1	1	1	1	1	1	1	1	1	1	1	0.99	0.99	0.97	0.94	0.88	0.94	0.97	0.99	0.99	1	1	1	1	1	1	1	1	1	1	1
428	1	1	1	1	1	1	1	1	1	1	1	0.99	0.98	0.96	0.92	0.85	0.92	0.96	0.98	0.99	1	1	1	1	1	1	1	1	1	1	1
426	1	1	1	1	1	1	1	1	1	1	1	0.99	0.98	0.95	0.9	0.8	0.9	0.95	0.98	0.99	1	1	1	1	1	1	1	1	1	1	1
424	1	1	1	1	1	1	1	1	1	1	0.99	0.99	0.97	0.93	0.86	0.74	0.86	0.93	0.97	0.99	0.99	1	1	1	1	1	1	1	1	1	1
422	1	1	1	1	1	1	1	1	1	1	0.99	0.98	0.96	0.91	0.82	0.68	0.82	0.91	0.96	0.98	0.99	1	1	1	1	1	1	1	1	1	1
420	1	1	1	1	1	1	1	1	1	0.99	0.99	0.97	0.94	0.88	0.77	0.61	0.77	0.88	0.94	0.97	0.99	0.99	1	1	1	1	1	1	1	1	1
418	1	1	1	1	1	1	1	1	1	0.99	0.98	0.96	0.92	0.84	0.71	0.53	0.71	0.84	0.92	0.96	0.98	0.99	1	1	1	1	1	1	1	1	1
416	1	1	1	1	1	1	1	1	1	0.99	0.98	0.95	0.9	0.8	0.64	0.45	0.64	0.8	0.9	0.95	0.98	0.99	1	1	1	1	1	1	1	1	1
414	1	1	1	1	1	1	1	1	0.99	0.99	0.97	0.93	0.86	0.74	0.56	0.37	0.56	0.74	0.86	0.93	0.97	0.99	0.99	1	1	1	1	1	1	1	1
412	1	1	1	1	1	1	1	1	0.99	0.98	0.96	0.91	0.82	0.68	0.49	0.3	0.49	0.68	0.82	0.91	0.96	0.98	0.99	1	1	1	1	1	1	1	1
410	1	1	1	1	1	1	1	0.99	0.99	0.97	0.94	0.88	0.77	0.6	0.41	0.24	0.41	0.6	0.77	0.88	0.94	0.97	0.99	0.99	1	1	1	1	1	1	1
408	1	1	1	1	1	1	1	0.99	0.98	0.96	0.92	0.84	0.71	0.52	0.33	0.19	0.33	0.52	0.71	0.84	0.92	0.96	0.98	0.99	1	1	1	1	1	1	1
406	1	1	1	1	1	1	0.99	0.99	0.98	0.95	0.89	0.79	0.64	0.44	0.27	0.14	0.27	0.44	0.64	0.79	0.89	0.95	0.98	0.99	0.99	1	1	1	1	1	1
404	1	1	1	1	1	1	0.99	0.98	0.97	0.93	0.86	0.74	0.56	0.37	0.21	0.11	0.21	0.37	0.56	0.74	0.86	0.93	0.97	0.98	0.99	1	1	1	1	1	1
402	1	1	1	1	1	1	0.99	0.98	0.96	0.91	0.82	0.67	0.48	0.3	0.16	0.08	0.16	0.3	0.48	0.67	0.82	0.91	0.96	0.98	0.99	1	1	1	1	1	1
400	1	1	1	1	1	0.99	0.99	0.97	0.94	0.88	0.77	0.6	0.4	0.24	0.12	0.06	0.12	0.24	0.4	0.6	0.77	0.88	0.94	0.97	0.99	0.99	1	1	1	1	1
398	1	1	1	1	1	0.99	0.98	0.96	0.92	0.84	0.7	0.52	0.33	0.18	0.09	0.04	0.09	0.18	0.33	0.52	0.7	0.84	0.92	0.96	0.98	0.99	1	1	1	1	1
396	1	1	1	1	0.99	0.99	0.98	0.95	0.89	0.79	0.63	0.44	0.26	0.14	0.07	0.03	0.07	0.14	0.26	0.44	0.63	0.79	0.89	0.95	0.98	0.99	0.99	1	1	1	1
394	1	1	1	1	0.99	0.98	0.96	0.91	0.82	0.67	0.48	0.29	0.16	0.08	0.04	0.02	0.04	0.08	0.16	0.29	0.48	0.67	0.82	0.91	0.96	0.98	0.99	1	1	1	1
392	1	1	1	1	0.99	0.98	0.97	0.93	0.86	0.73	0.56	0.36	0.21	0.11	0.05	0.02	0.05	0.11	0.21	0.36	0.56	0.73	0.86	0.93	0.97	0.98	0.99	1	1	1	1
390	1	1	0.99	0.98	0.97	0.93	0.86	0.73	0.55	0.36	0.2	0.1	0.05	0.02	0.01	0.01	0.01	0.02	0.05	0.1	0.2	0.36	0.55	0.73	0.86	0.93	0.97	0.98	0.99	1	1
388	1	1	0.99	0.99	0.98	0.95	0.89	0.79	0.63	0.44	0.26	0.14	0.07	0.03	0.01	0.01	0.01	0.03	0.07	0.14	0.26	0.44	0.63	0.79	0.89	0.95	0.98	0.99	0.99	1	1
386	1	1	1	0.99	0.98	0.96	0.92	0.84	0.7	0.52	0.33	0.18	0.09	0.04	0.02	0.01	0.02	0.04	0.09	0.18	0.33	0.52	0.7	0.84	0.92	0.96	0.98	0.99	1	1	1
384	1	1	1	0.99	0.99	0.97	0.94	0.88	0.76	0.59	0.4	0.23	0.12	0.06	0.03	0.01	0.03	0.06	0.12	0.23	0.4	0.59	0.76	0.88	0.94	0.97	0.99	0.99	1	1	1
382	1	0.99	0.99	0.97	0.94	0.87	0.76	0.59	0.4	0.23	0.12	0.06	0.03	0.01	0.01	0	0.01	0.01	0.03	0.06	0.12	0.23	0.4	0.59	0.76	0.87	0.94	0.97	0.99	0.99	1
380	1	1	0.99	0.98	0.95	0.91	0.81	0.67	0.48	0.29	0.16	0.08	0.04	0.02	0.01	0	0.01	0.02	0.04	0.08	0.16	0.29	0.48	0.67	0.81	0.91	0.95	0.98	0.99	1	1

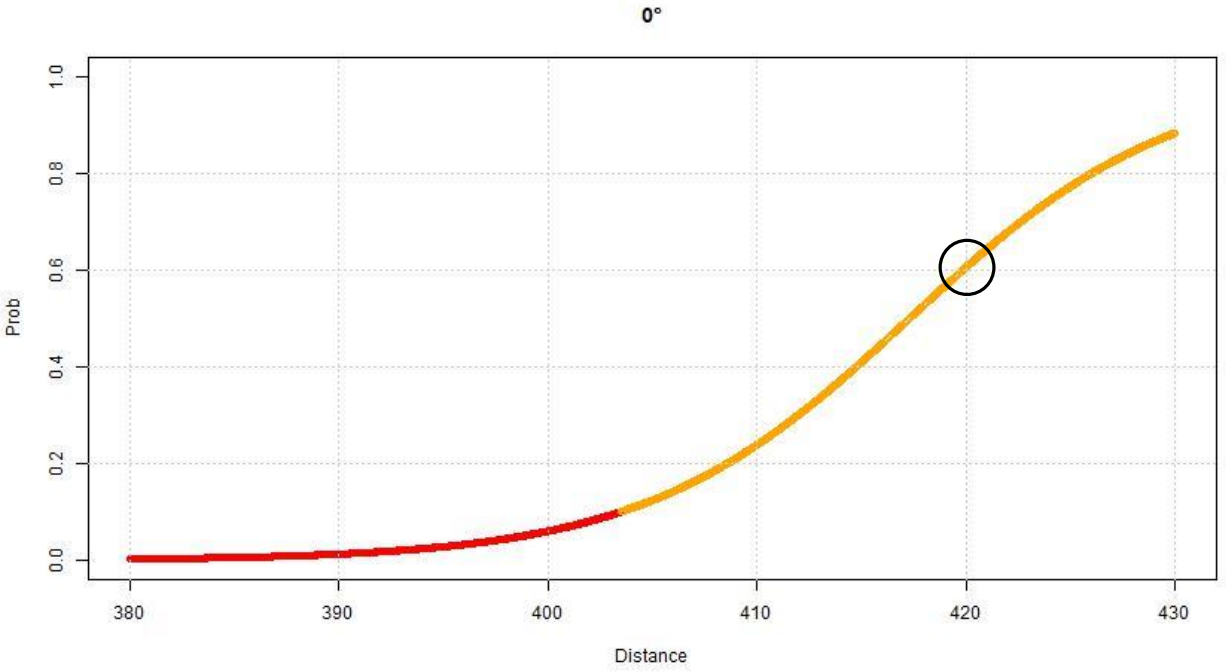
CHANGE IN PROBABILITY BY CHANGE IN DISTANCE

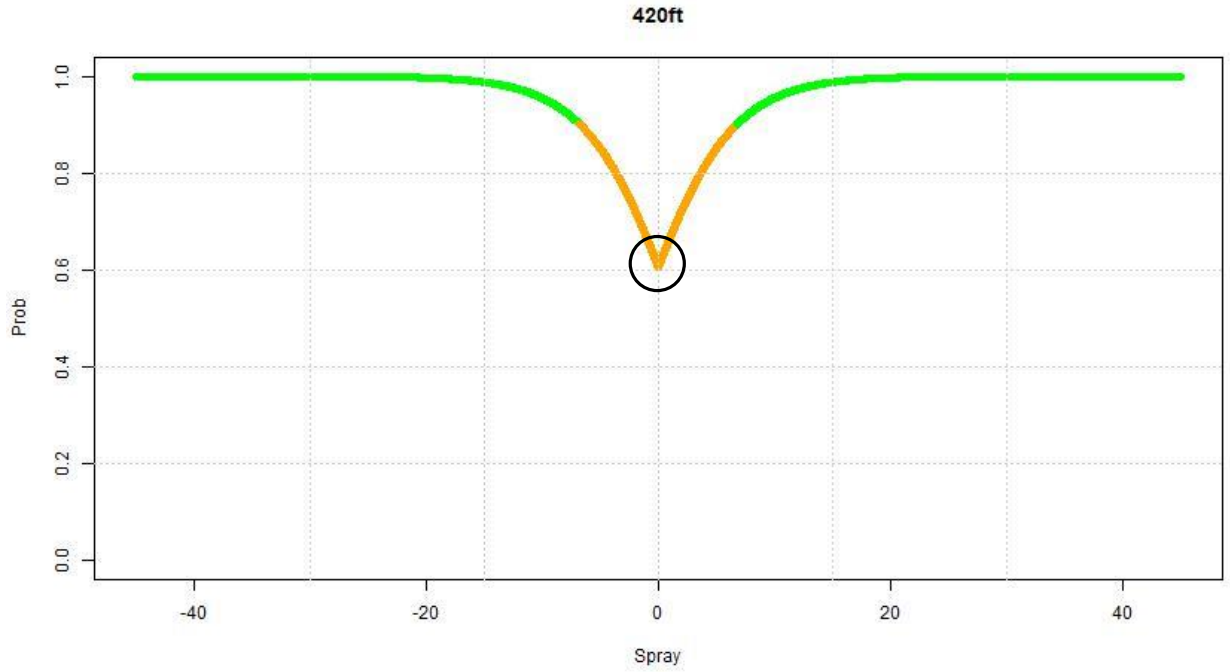


CHANGE IN PROBABILITY BY CHANGE IN DIRECTION



CONSIDER

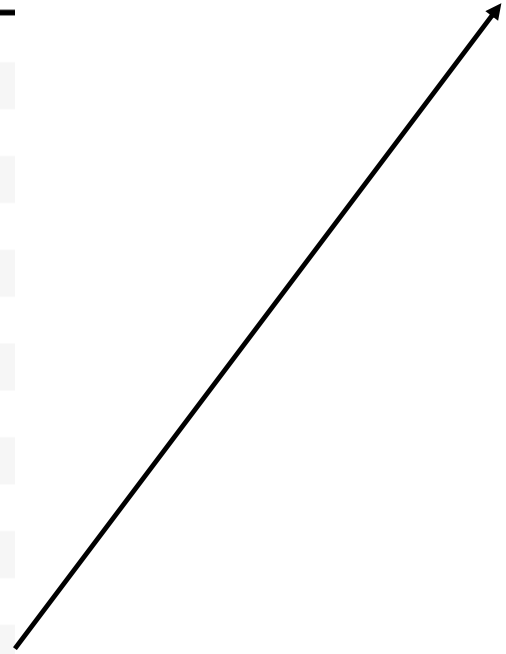

0°
Prob
0.0
0.2
0.4
0.6
0.8
1.0
380
390
400
410
420
430
Distance


420ft
Prob
0.0
0.2
0.4
0.6
0.8
1.0
-40
-20
0
20
40
Spray

OTHER MODELS

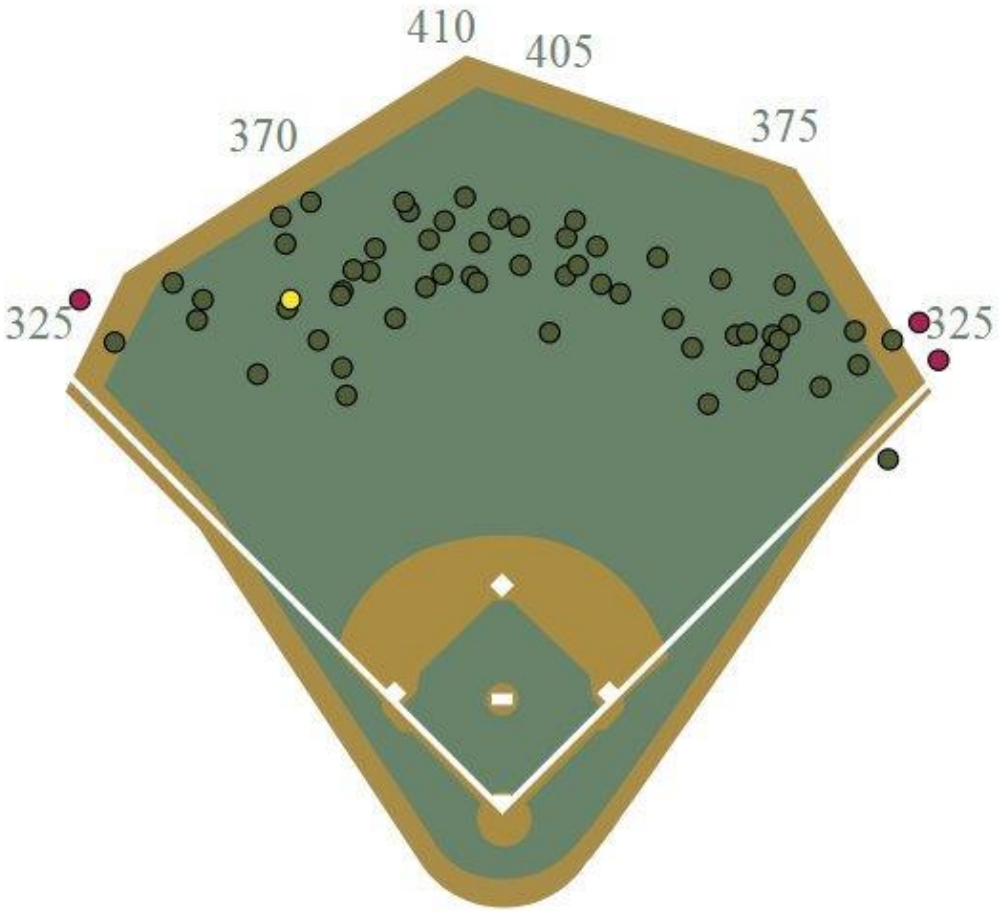
LAUNCH ANGLE & EXIT VELOCITY

Exit Velocity (MPH)	HR %
123	0.0
122	0.0
121	100.0
120	0.0
119	45.5
118	18.2
117	28.6
116	24.4
115	21.1
114	24.1
113	22.2
112	23.6
111	21.2
110	21.4
109	22.2
108	22.1
107	21.8
106	20.7
105	19.2
104	17.3



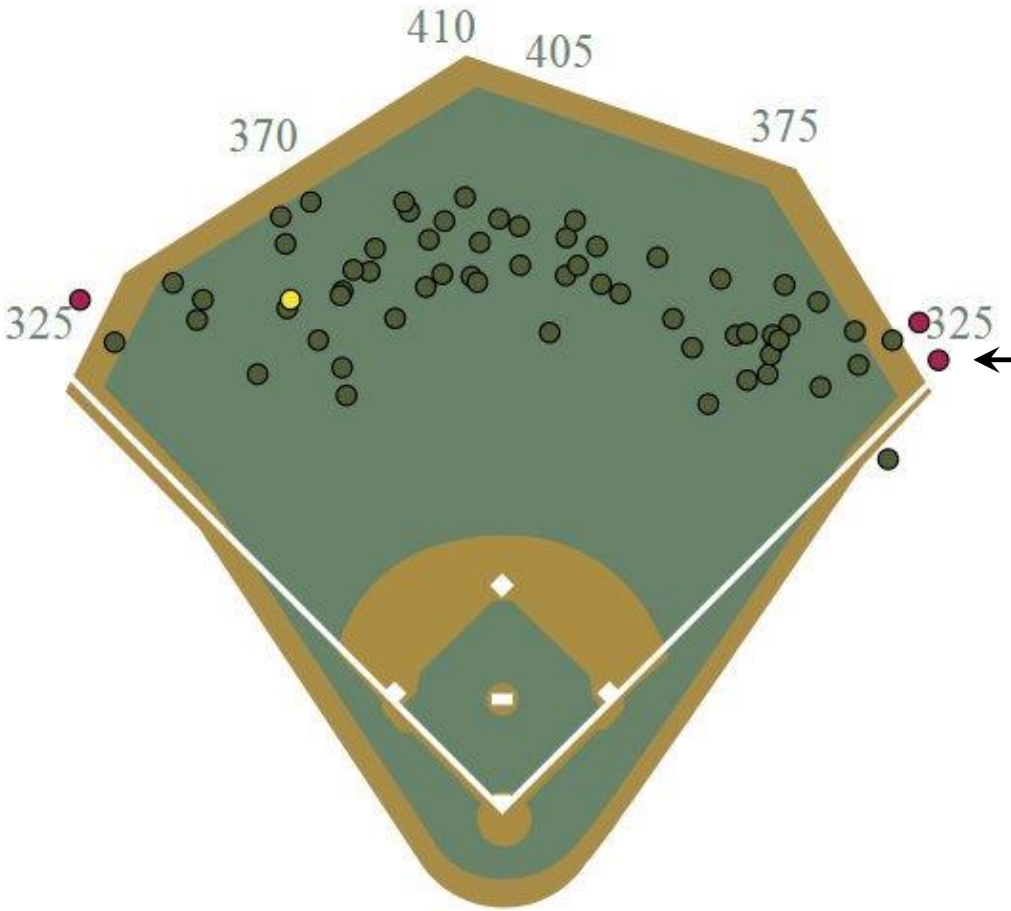
Launch Angle (Deg)	HR %
51	0.0
50	0.0
49	0.0
48	100.0
43	100.0
42	100.0
40	100.0
39	100.0
38	66.7
37	100.0
36	100.0
35	100.0
34	100.0
33	100.0
32	94.7
31	100.0
30	100.0
29	100.0
28	96.7
27	92.9

LAUNCH ANGLE & EXIT VELOCITY



94 MPH, 41°, BA: 0.063 1B%: 0 2B%: 2 3B%: 0 HR %: 5

LAUNCH ANGLE & EXIT VELOCITY



5%

94 MPH, 41°, BA: 0.063 1B%: 0 2B%: 2 3B%: 0 HR %: 5

AUGMENTED HIT PROBABILITY

- Still uses launch angle and exit velocity
- If the ball was hit close to a generic fence line, spray direction was included
- Better estimates higher probabilities
- Note: this model has not been released yet

APPLICATION

THESE TWO FLY OUTS

Jake Lamb

- Launch angle: 26˚
- Exit velocity: 100 mph

Matt Adams

- Launch angle: 26˚
- Exit velocity: 100 mph

THESE TWO FLY OUTS

Jake Lamb

- Launch angle: 26˚
- Exit velocity: 100 mph

46%

Matt Adams

- Launch angle: 26˚
- Exit velocity: 100 mph

46%

THESE TWO FLY OUTS

Jake Lamb

- Launch angle: 26˚
- Exit velocity: 100 mph

46%

- Distance: 385 feet

Matt Adams

- Launch angle: 26˚
- Exit velocity: 100 mph

46%

- Distance: 389 feet

THESE TWO FLY OUTS

Jake Lamb

- Launch angle: 26˚
- Exit velocity: 100 mph

46%

- Distance: 385 feet
- **Spray angle: -23˚**

Matt Adams

- Launch angle: 26˚
- Exit velocity: 100 mph

46%

- Distance: 389 feet
- **Spray angle: -8˚**

THESE TWO FLY OUTS

Jake Lamb

- Launch angle: 26˚
- Exit velocity: 100 mph

46%

- Distance: 385 feet
- **Spray angle: -23˚**

72%

Matt Adams

- Launch angle: 26˚
- Exit velocity: 100 mph

46%

- Distance: 389 feet
- **Spray angle: -8˚**

8%

THESE TWO HOME RUNS

Chris Young

- Launch angle: 26˚
- Exit velocity: 100 mph

46%

Matt Wieters

- Launch angle: 26˚
- Exit velocity: 100 mph

46%

THESE TWO HOME RUNS

Chris Young

- Launch angle: 26˚
- Exit velocity: 100 mph

46%

- Distance: 399 feet

Matt Wieters

- Launch angle: 26˚
- Exit velocity: 100 mph

46%

- Distance: 403 feet

THESE TWO HOME RUNS

Chris Young

- Launch angle: 26˚
- Exit velocity: 100 mph

46%

- Distance: 399 feet
- **Spray angle: -32˚**

Matt Wieters

- Launch angle: 26˚
- Exit velocity: 100 mph

46%

- Distance: 403 feet
- **Spray angle: 3˚**

THESE TWO HOME RUNS

Chris Young

- Launch angle: 26˚
- Exit velocity: 100 mph

46%

- Distance: 399 feet
- **Spray angle: -32˚**

100%

Matt Wieters

- Launch angle: 26˚
- Exit velocity: 100 mph

46%

- Distance: 403 feet
- **Spray angle: 3˚**

18%

THIS SALVADOR PEREZ FLY OUT

LA & EV model

91% home run probability

LA=30˚

EV=106 mph

My model

97% home run probability

Distance=426

Angle=8˚

THIS MIGUEL CABRERA FLY OUT

LA & EV model

91% home run probability

LA=30˚

EV=108 mph

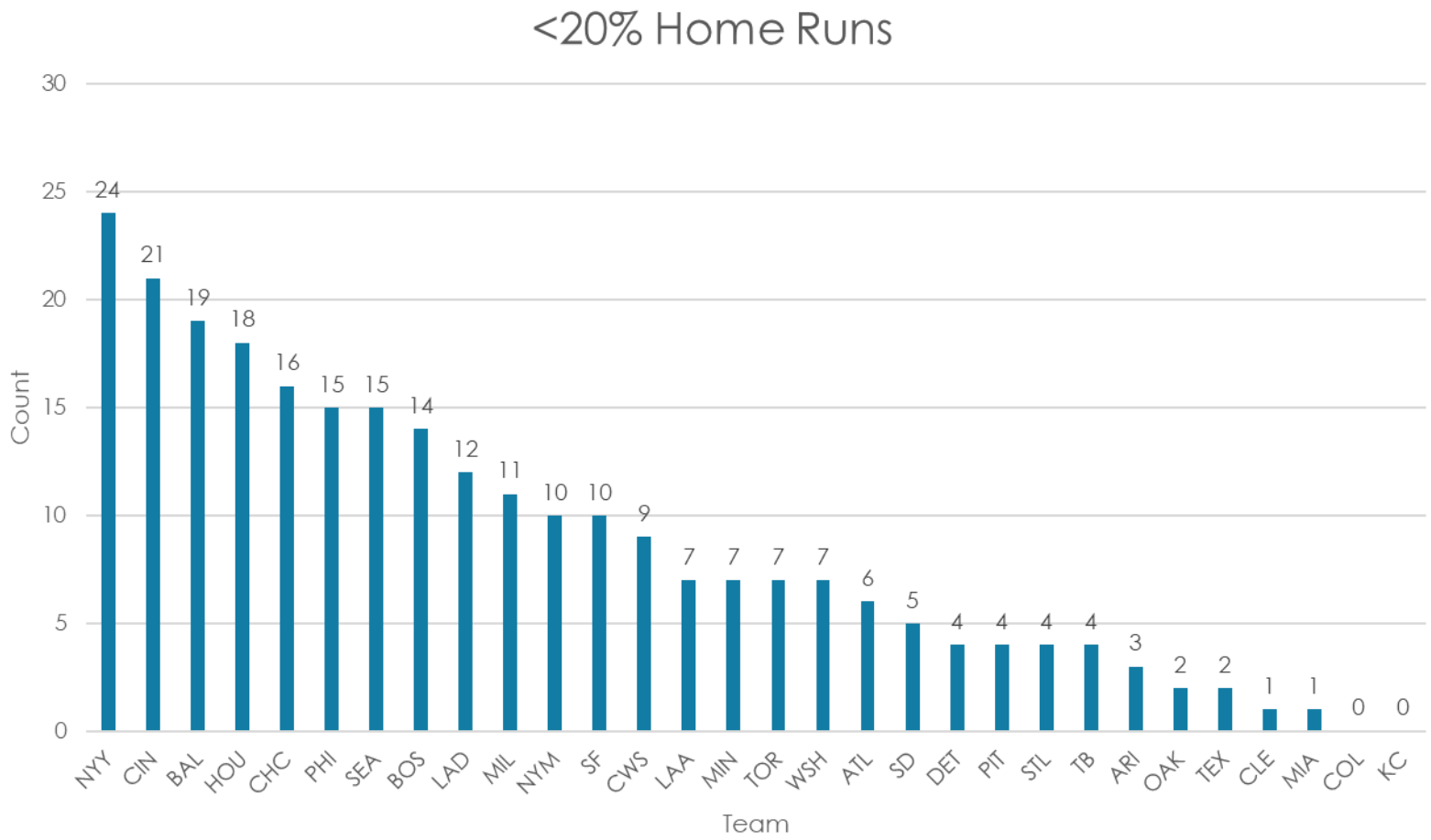
My model

1% home run probability

Distance=388

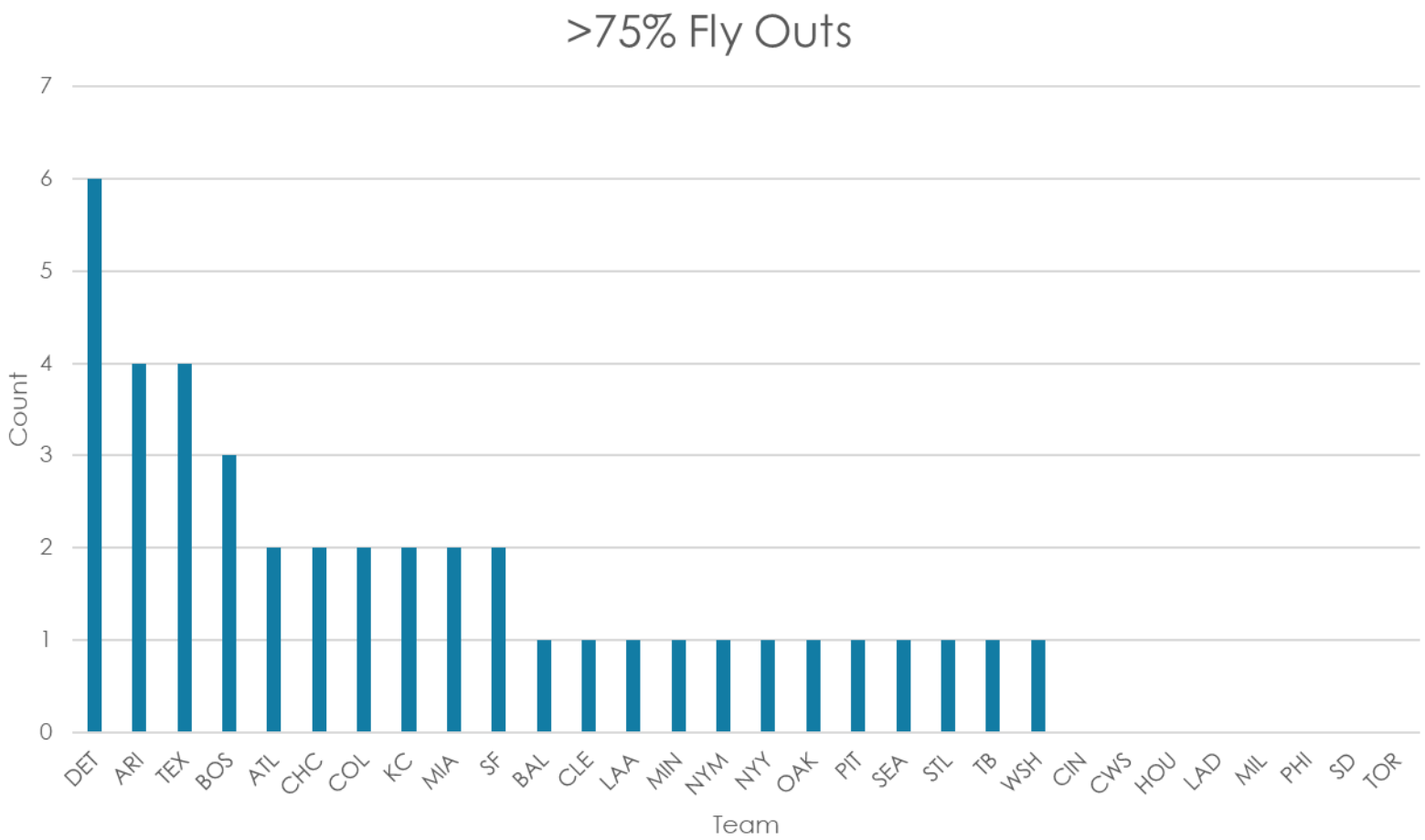
Angle=0˚

THE "WHERE" QUESTION



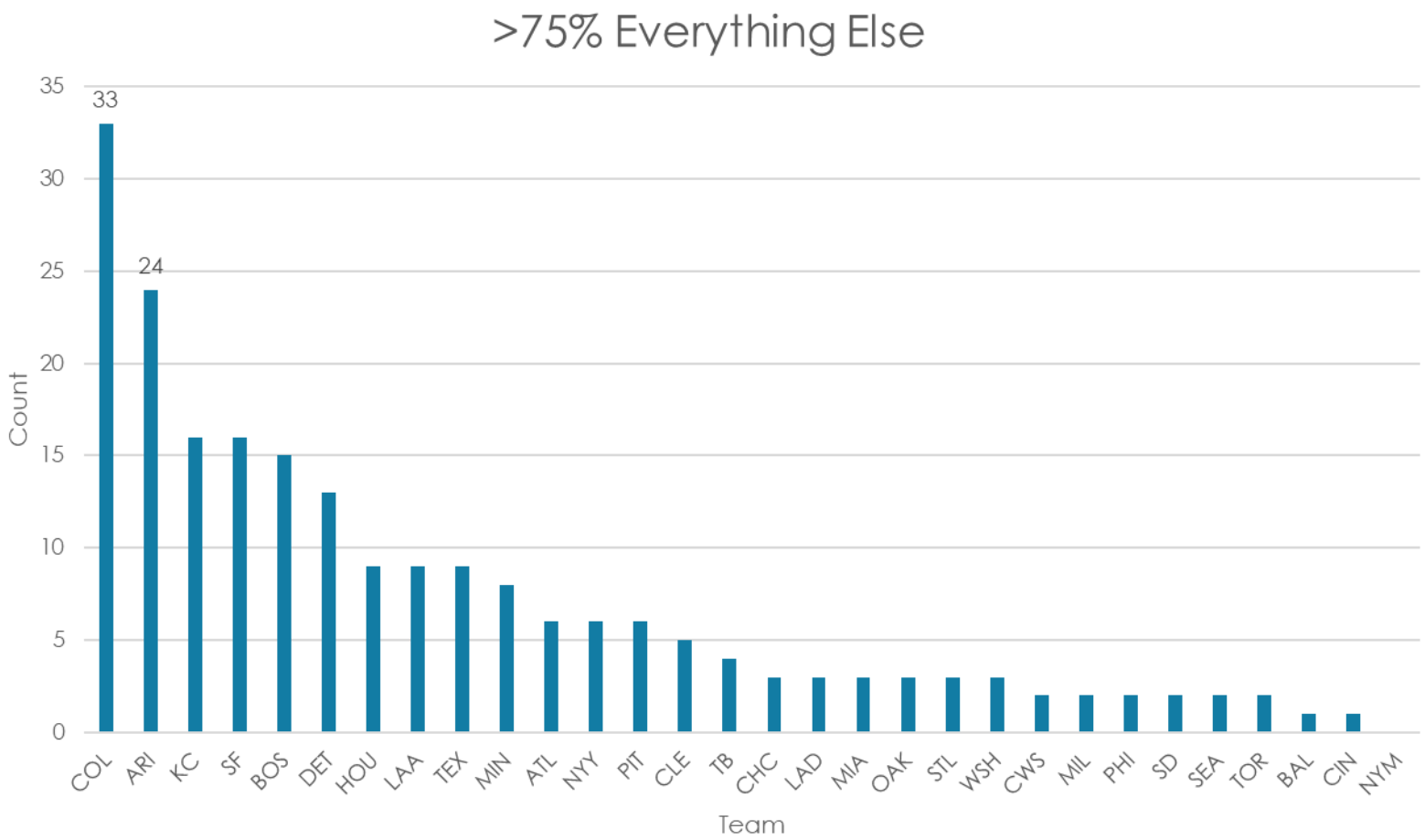
n=258

THE "WHERE" QUESTION



n=41

THE "WHERE" QUESTION



n=211

MOVING FORWARD

MOVING FORWARD

- Explaining the sharp dip in probability around 0˚
- Finding better ways to compare observed and predicted probabilities
- Keep improving!

THANK YOU!

- Committee members
  - Dr. Steve Ziebarth
  - Dr. Joe McKean
  - Tom Tango
- Family
- Everyone who came today!

QUESTIONS?