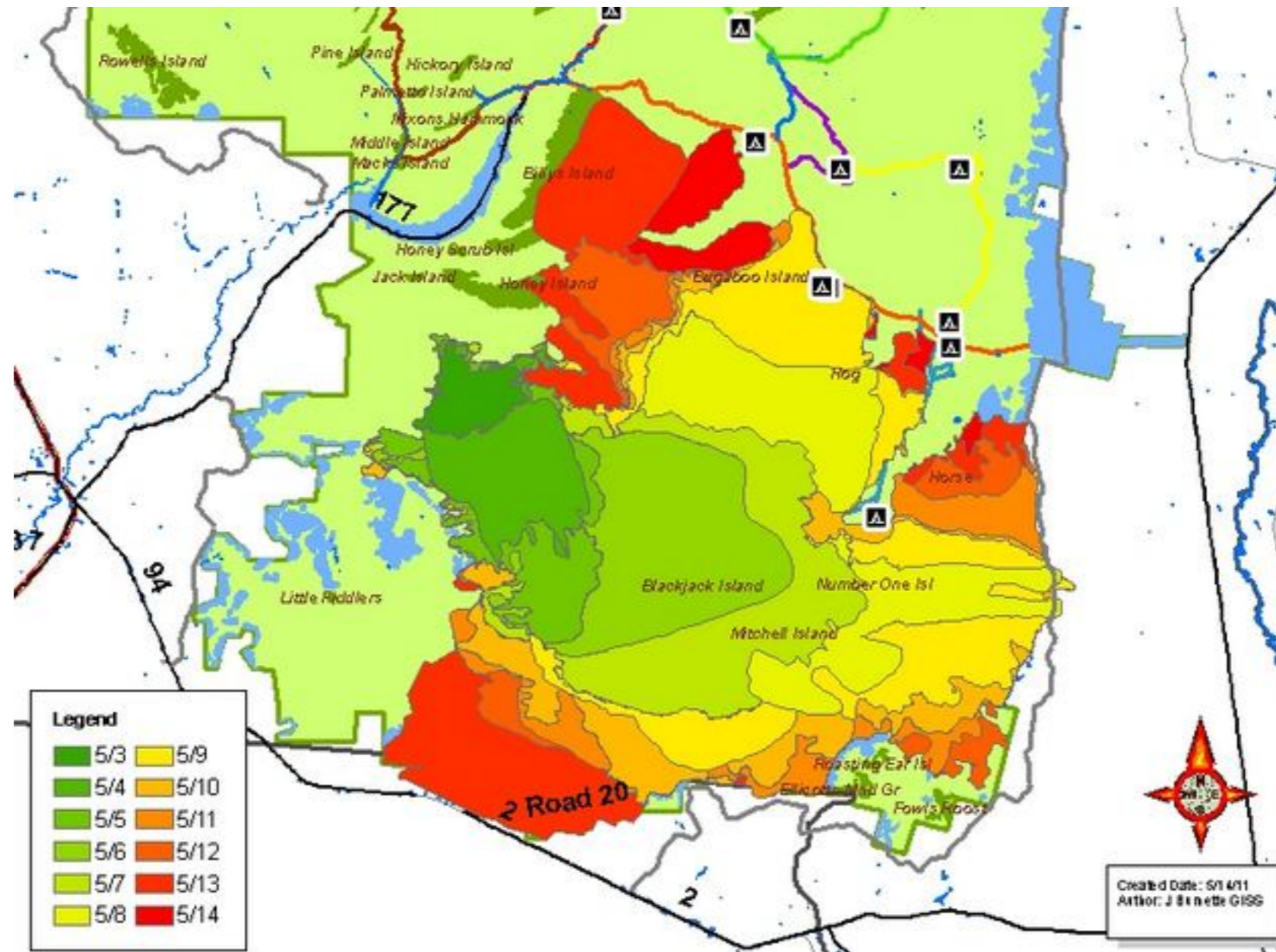


A Re-Evaluation of Critical Fire Weather in the Southeastern United States

Example Case

Afternoon surface temperature:	79 °F
Afternoon surface dewpoint:	43 °F
Minimum relative humidity:	26 %
Maximum wind speed:	16 mph
Maximum Fosberg index:	19
Energy release component:	35
100-hour dead fuel moisture:	16.3%
1000-hour dead fuel moisture:	16.1%
Burning Index:	37

Example Case

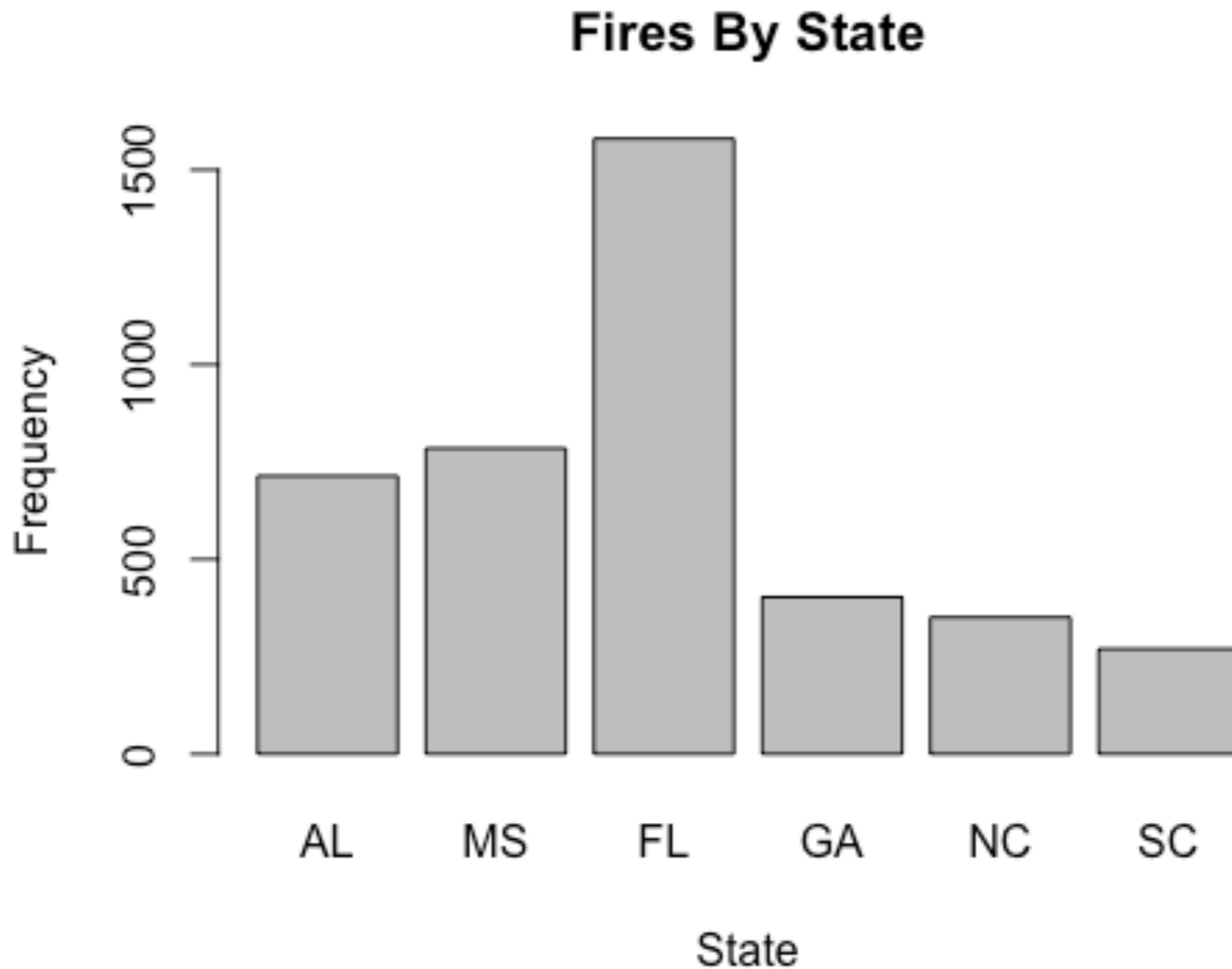


Honey Prairie Fire in Georgia (2011)

- 309,200 acres burned
- Persisted for 16 days
- Caused by lightning

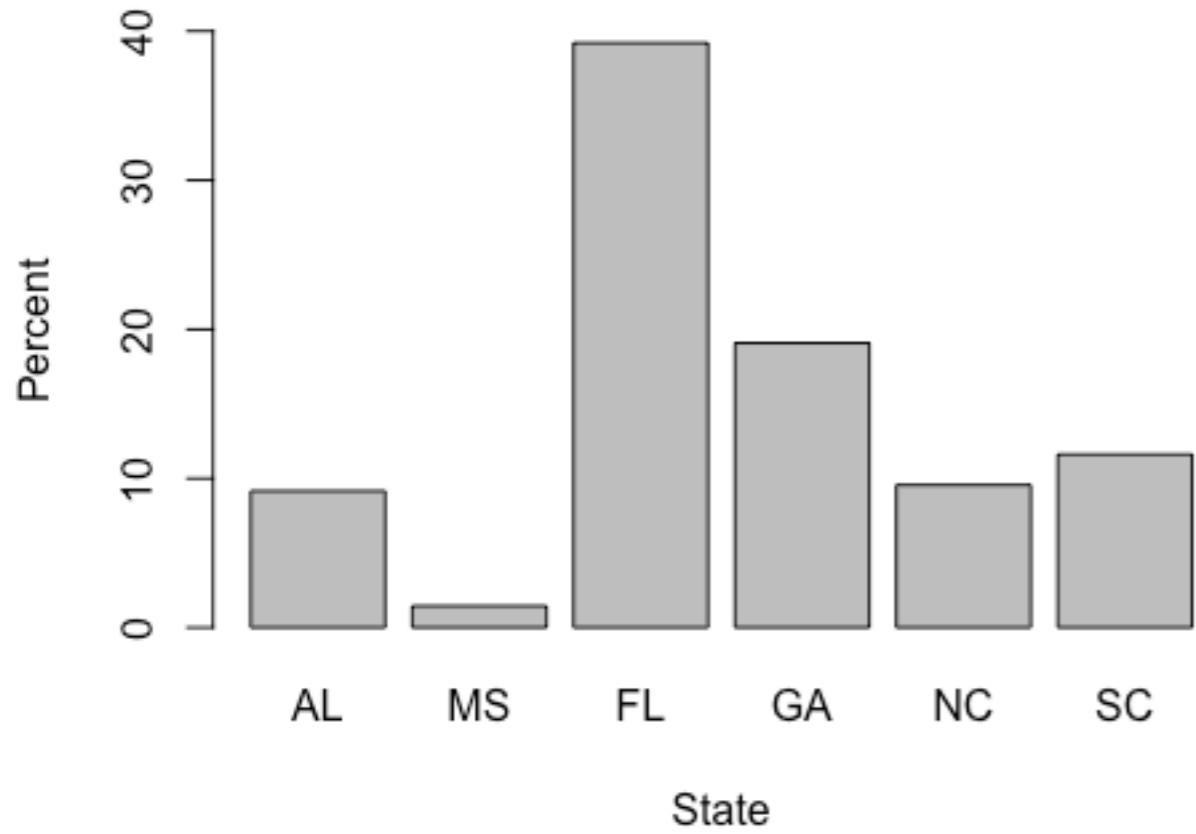
Research Outline

- Examined fires that burned at least 100 acres
- Fires from FL, GA, SC, NC, MS, AL in the years 2002-2013
- Basic overview (break down fires by state, cause, month)
- Analyzing individual parameters
- Bivariate analyses

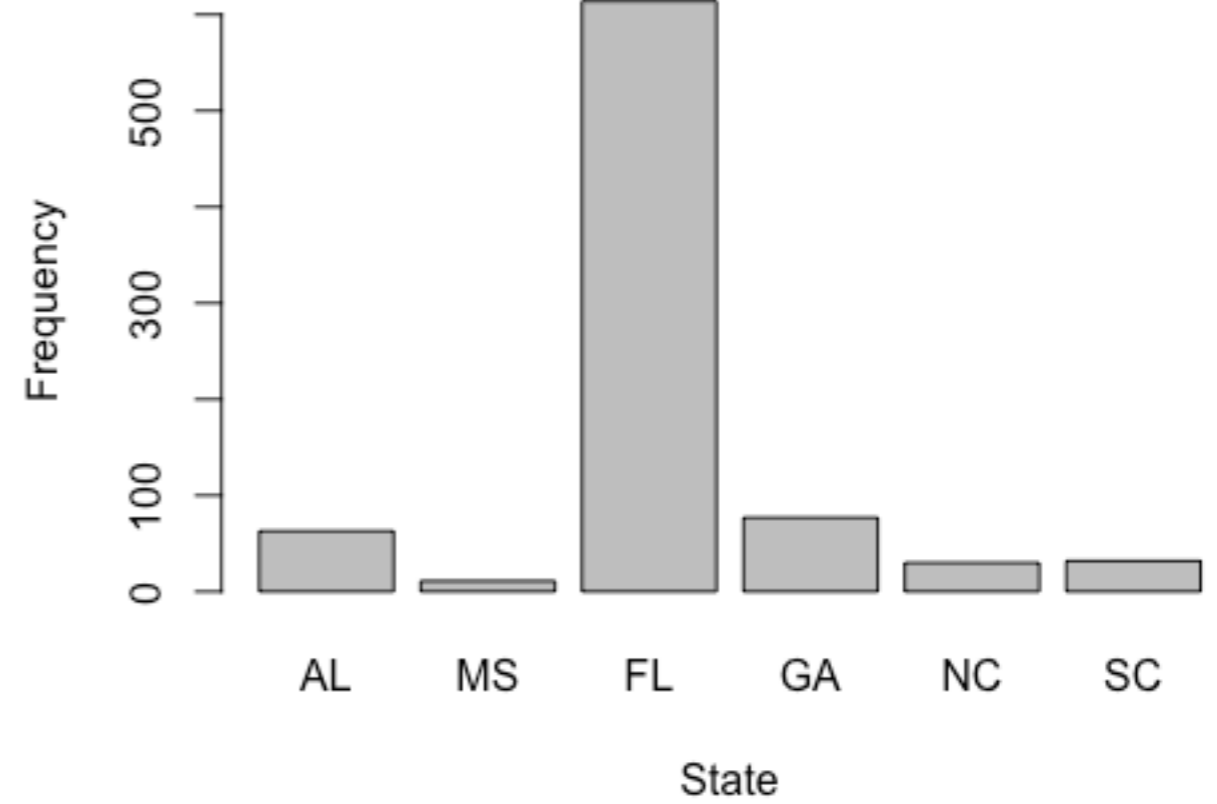


- Disproportionate number of fires occurred in Florida
 - Averaged about 110 fires per year 2002-2013
- Fewest number of fires in the Carolinas
 - Averaged about 29 fires per year 2002-2013

Percentage of Fires Caused by Lightning

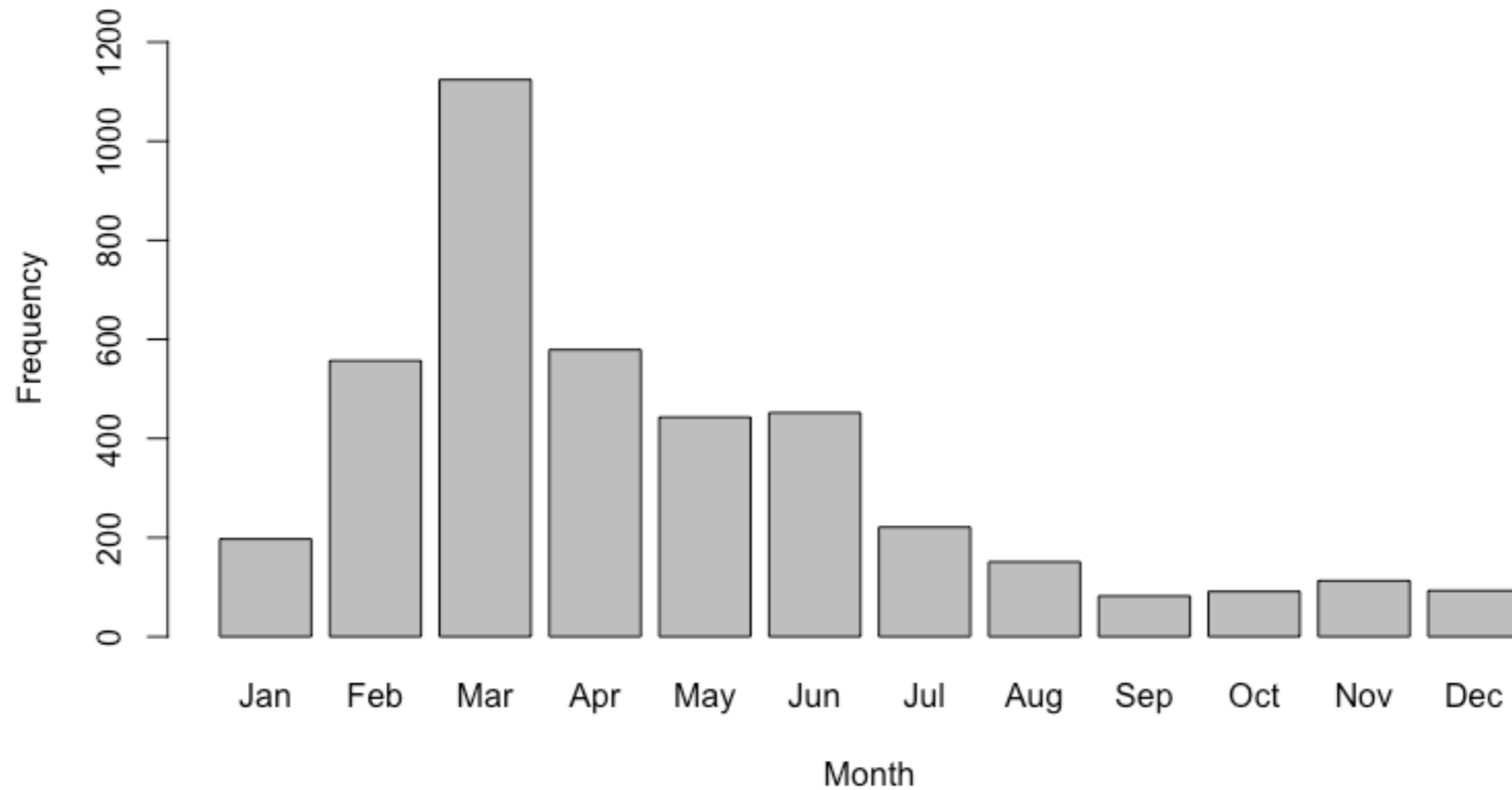


Lightning Fires By State



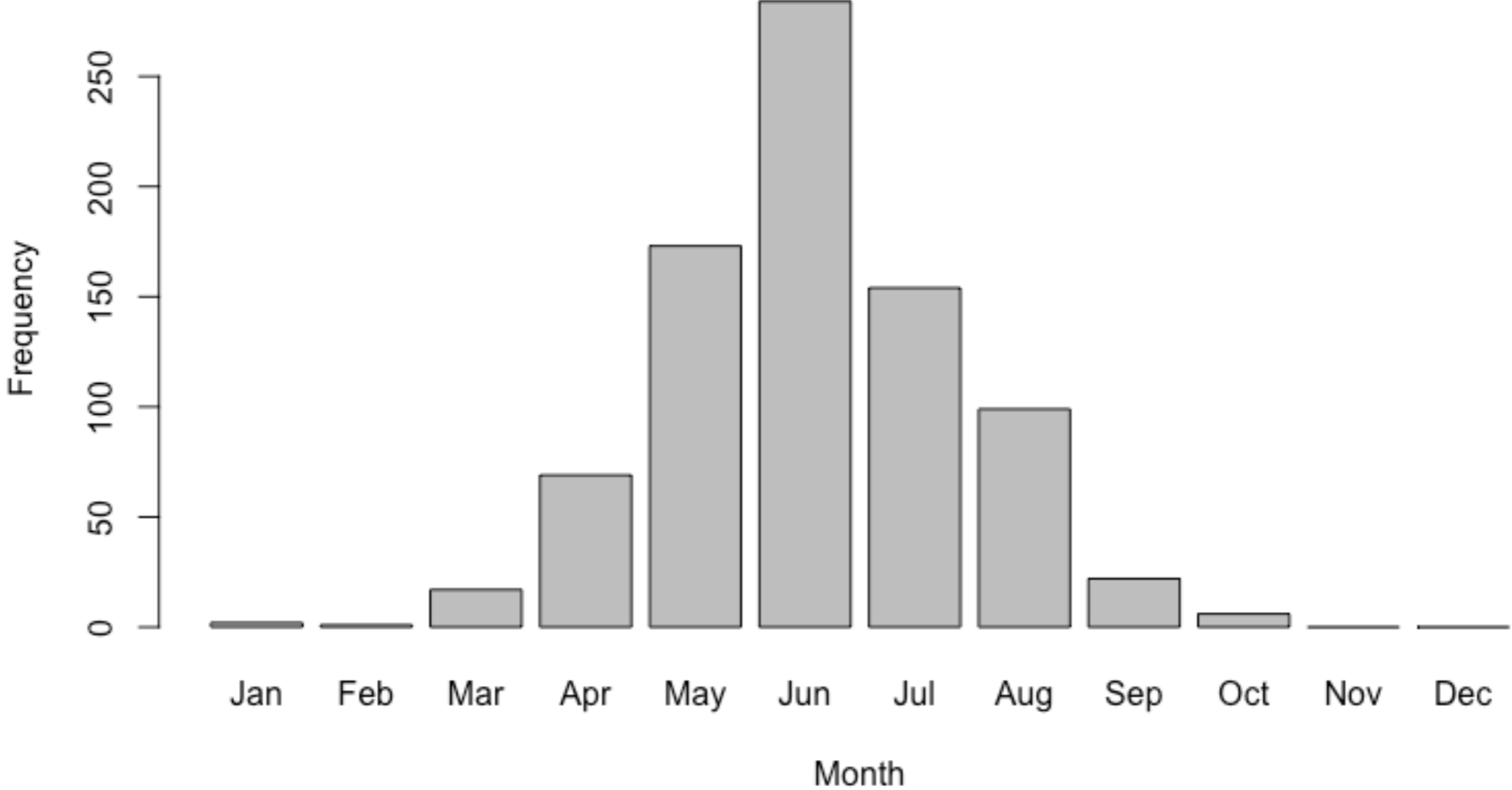
- Nearly half of all fires in Florida caused by lightning
- Very few fires in Mississippi caused by lightning

Fires By Month



- Fire weather season peaks in late winter/early spring
- Relatively inactive during late summer and fall

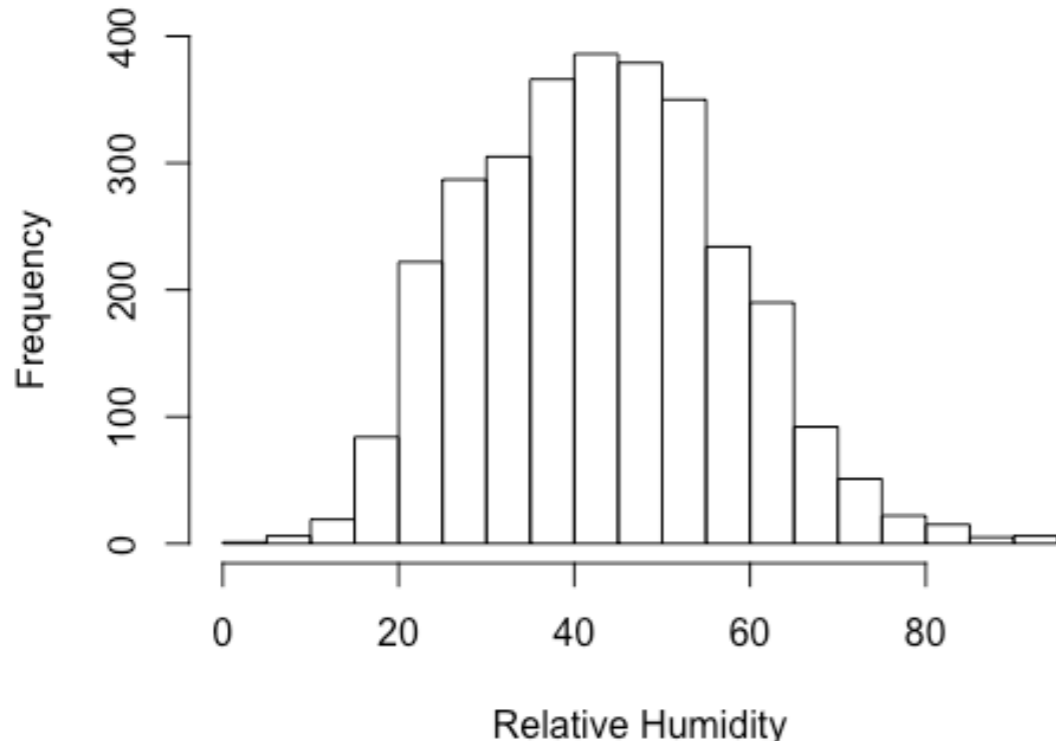
Lightning Fires By Month



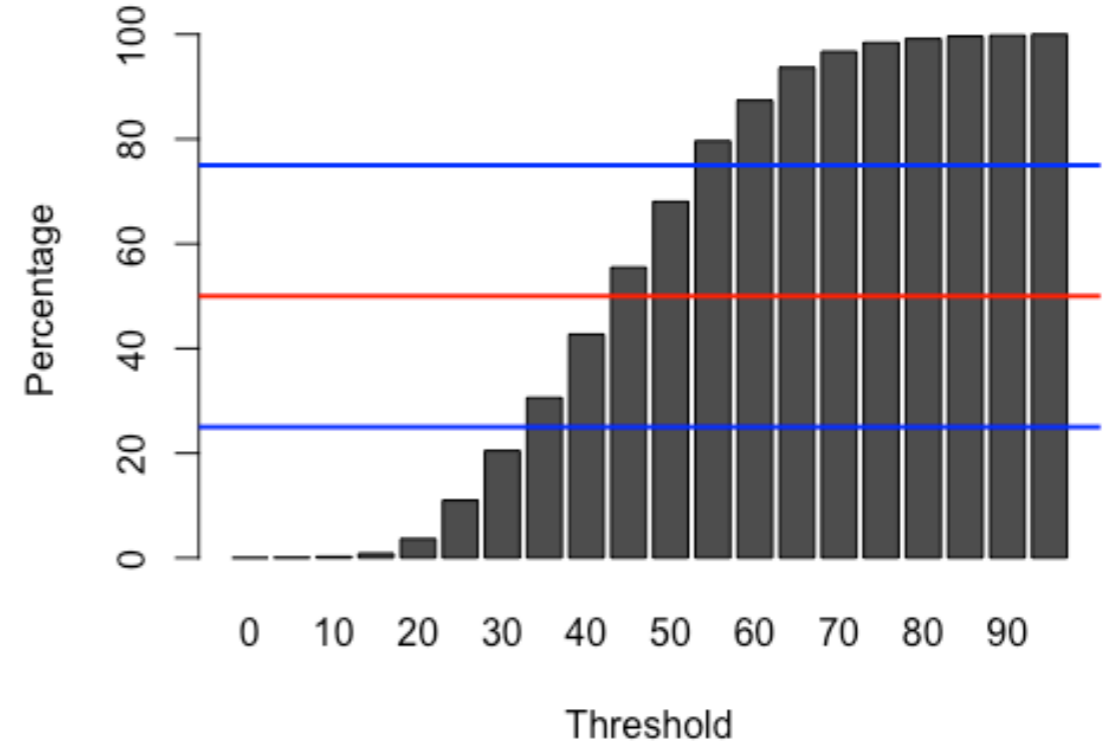
- Most lightning-caused fires occur in late spring/early summer

Relative Humidity

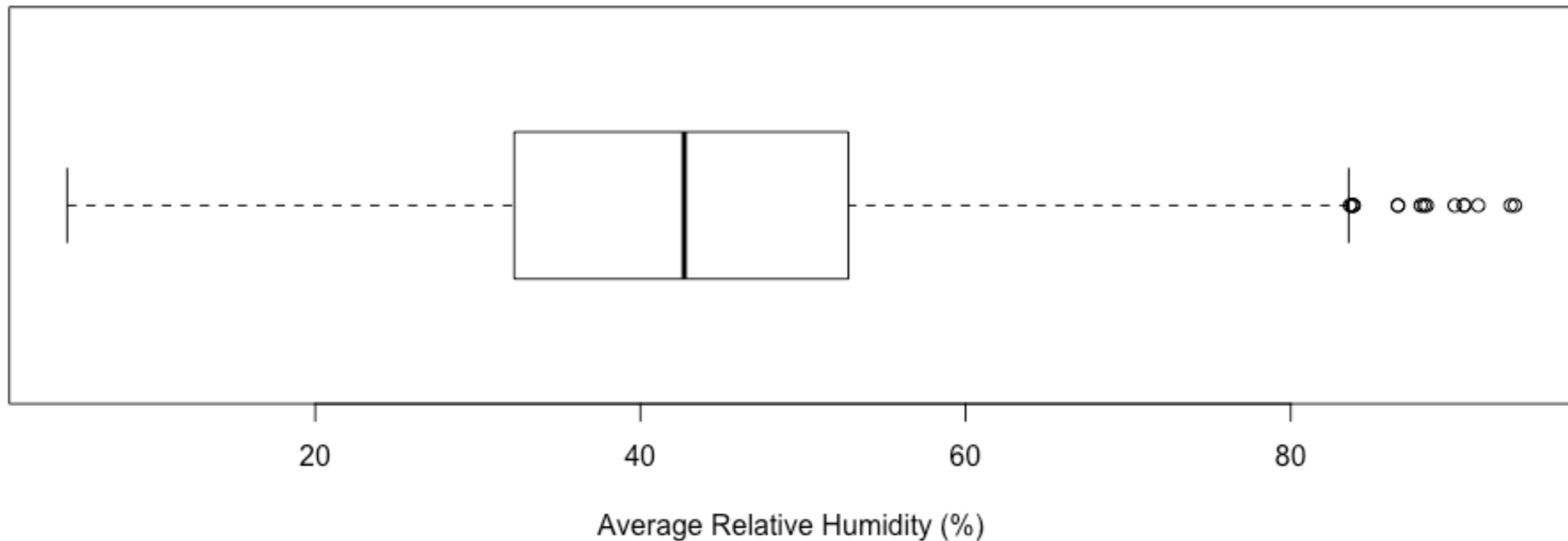
Average Relative Humidity Histogram



Percentile Plot of Relative Humidity

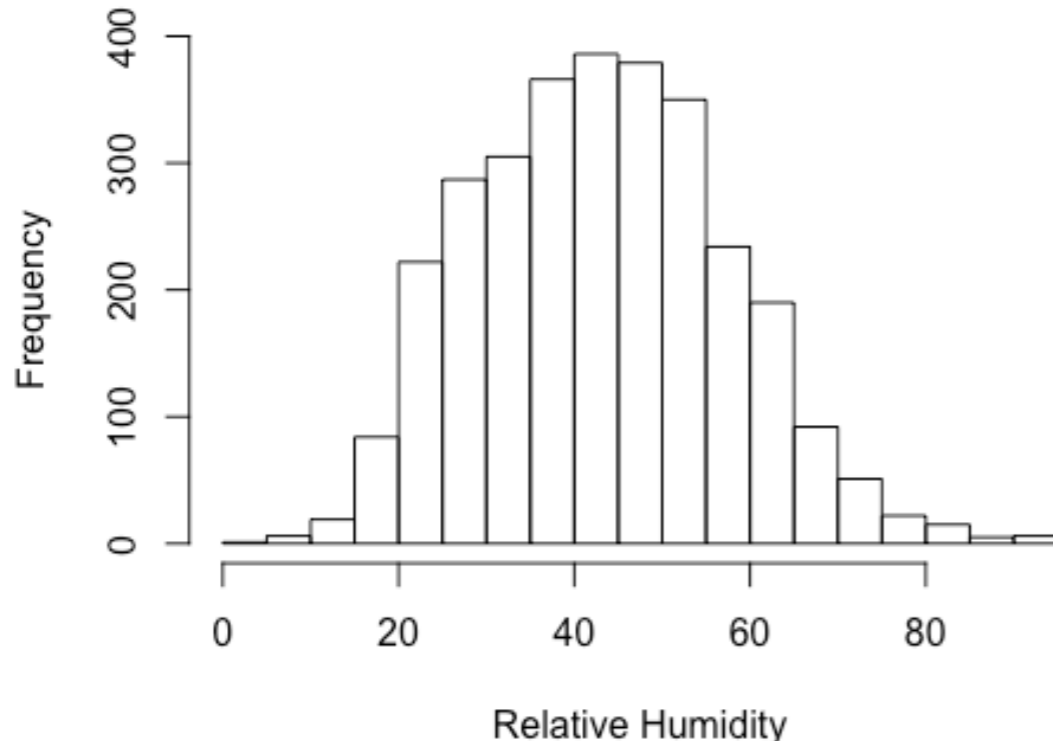


Average Relative Humidity Box Plot

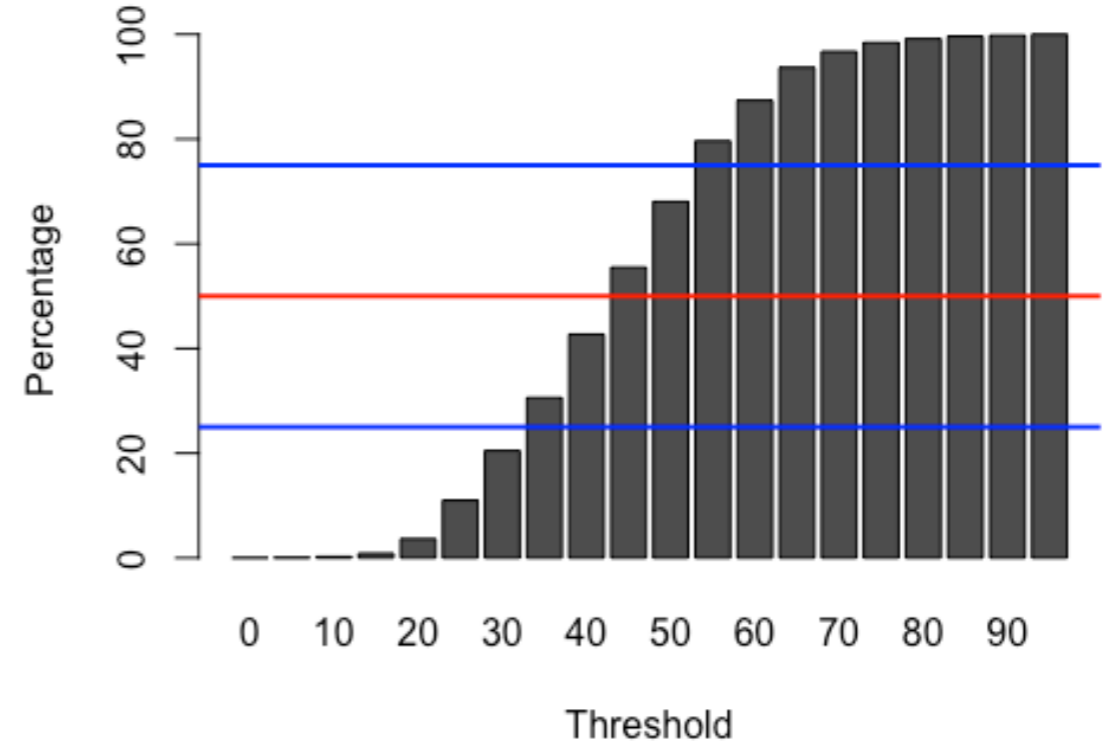


Relative Humidity

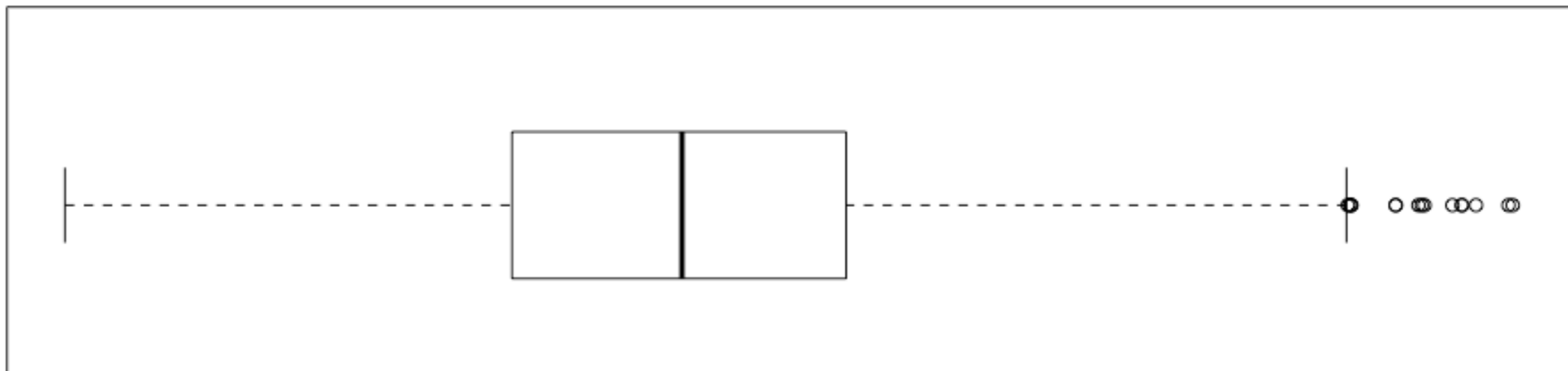
Average Relative Humidity Histogram



Percentile Plot of Relative Humidity



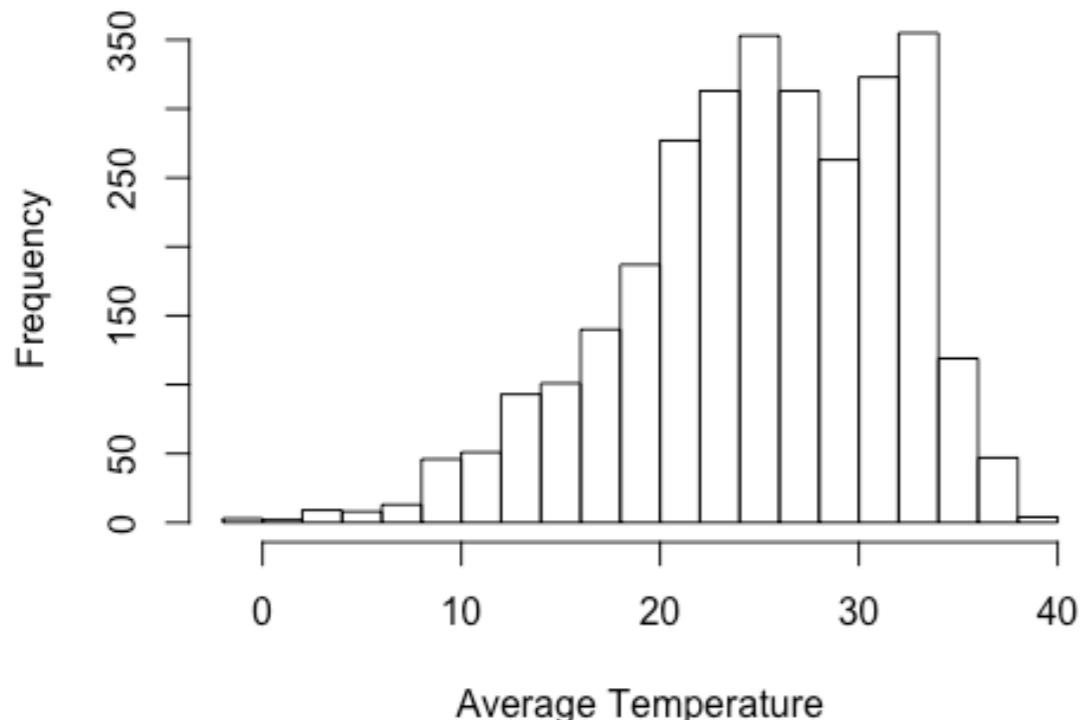
Average Relative Humidity Box Plot



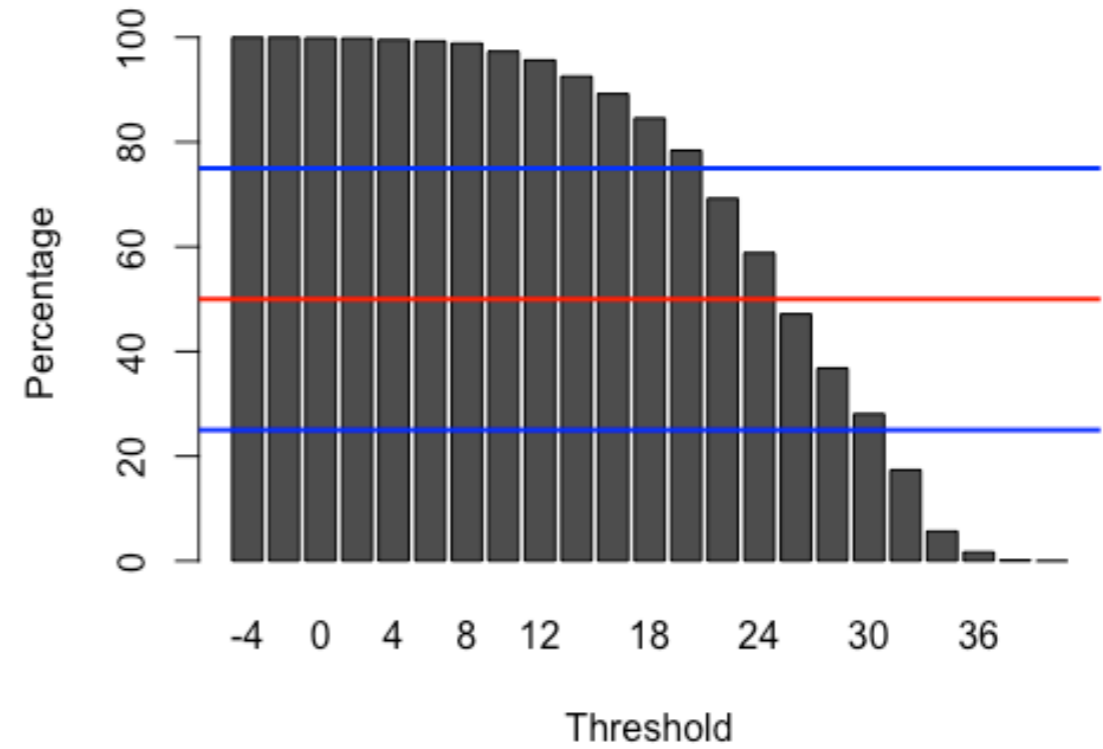
- 30% of all fires had relative humidities of 35% or less
- Broad distribution of relative humidity

Temperature

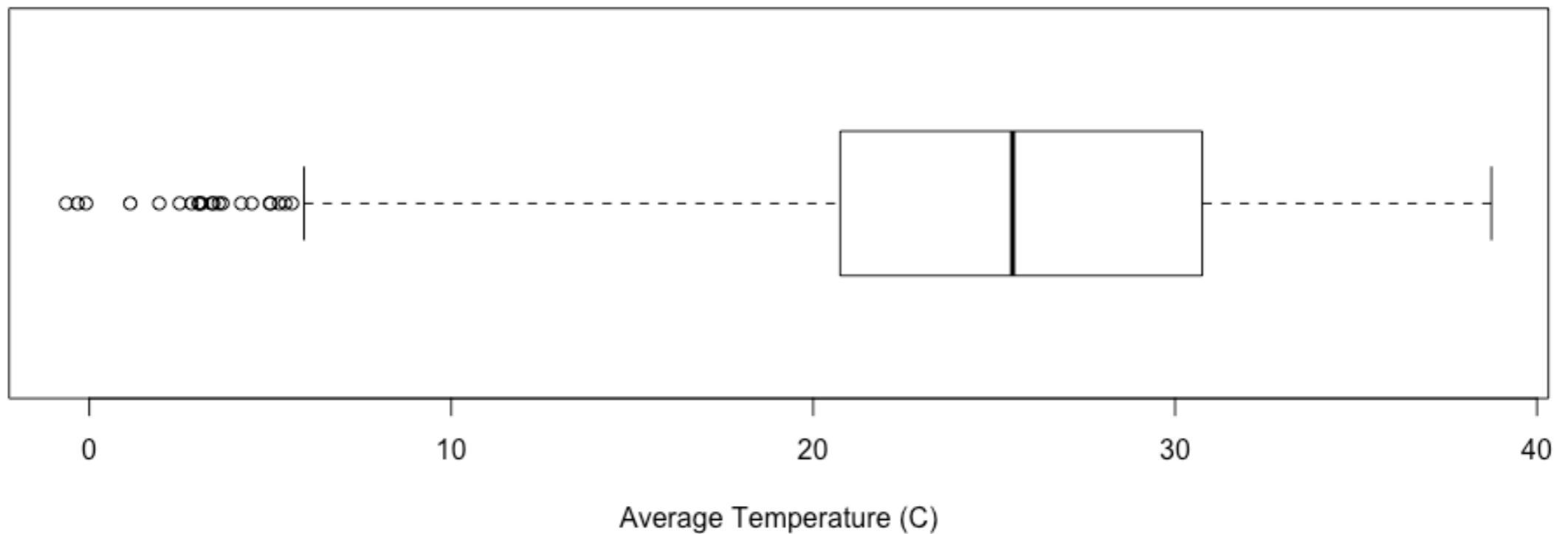
Average Temperature Histogram



Percentile Plot of Air Temperature

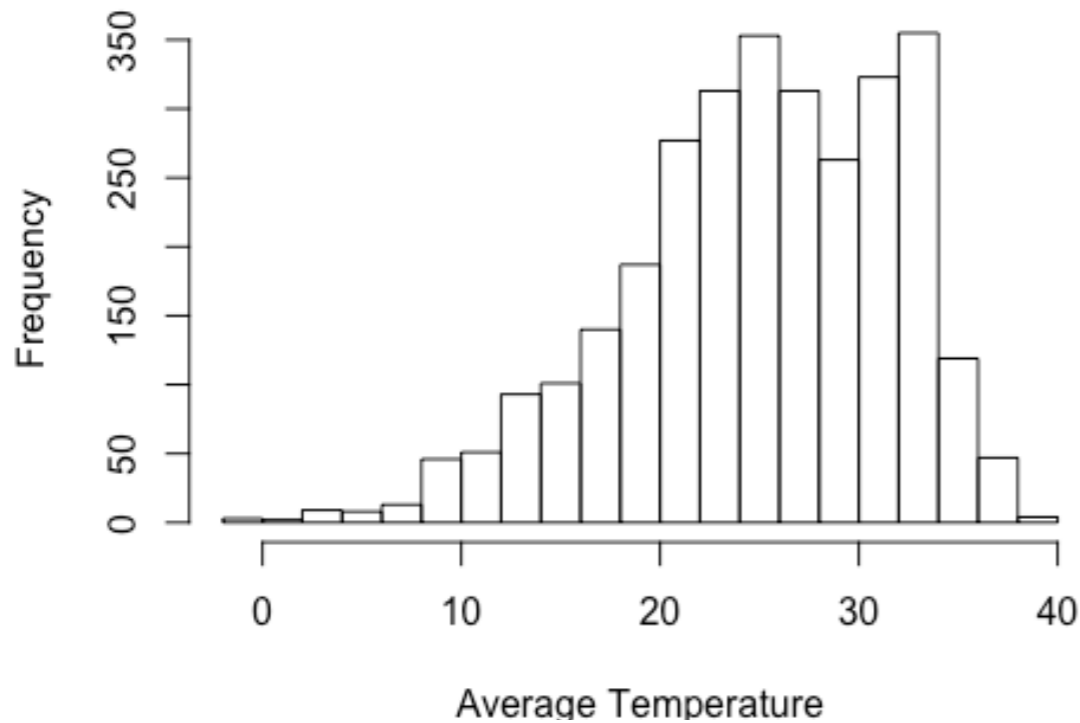


Average Temperature Box Plot

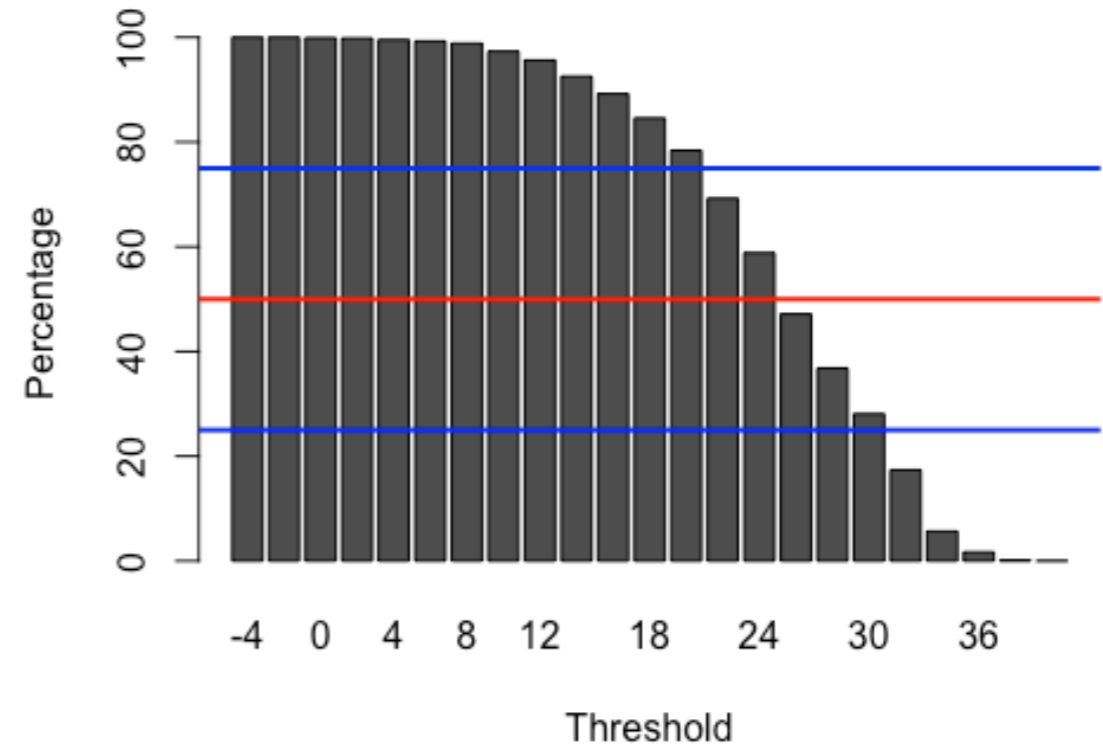


Temperature

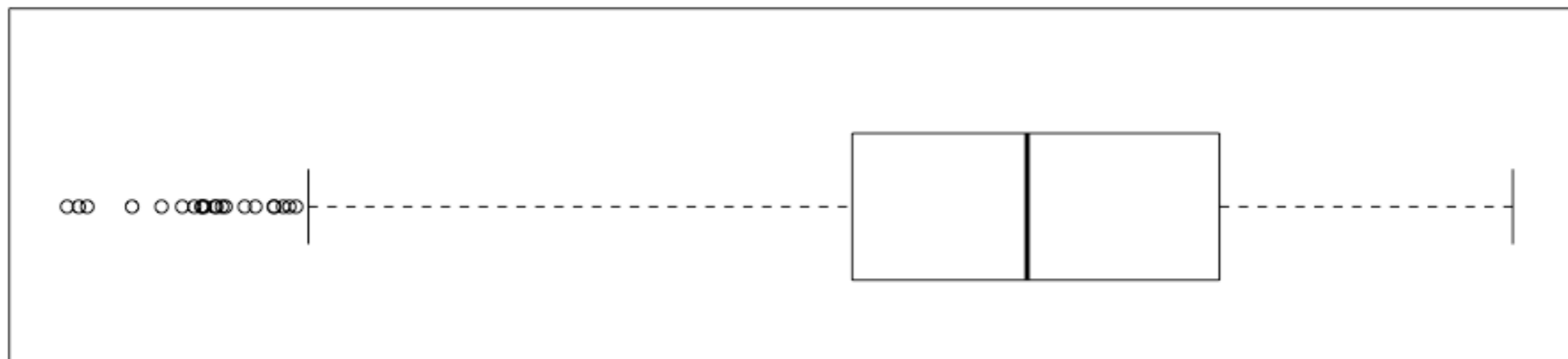
Average Temperature Histogram



Percentile Plot of Air Temperature



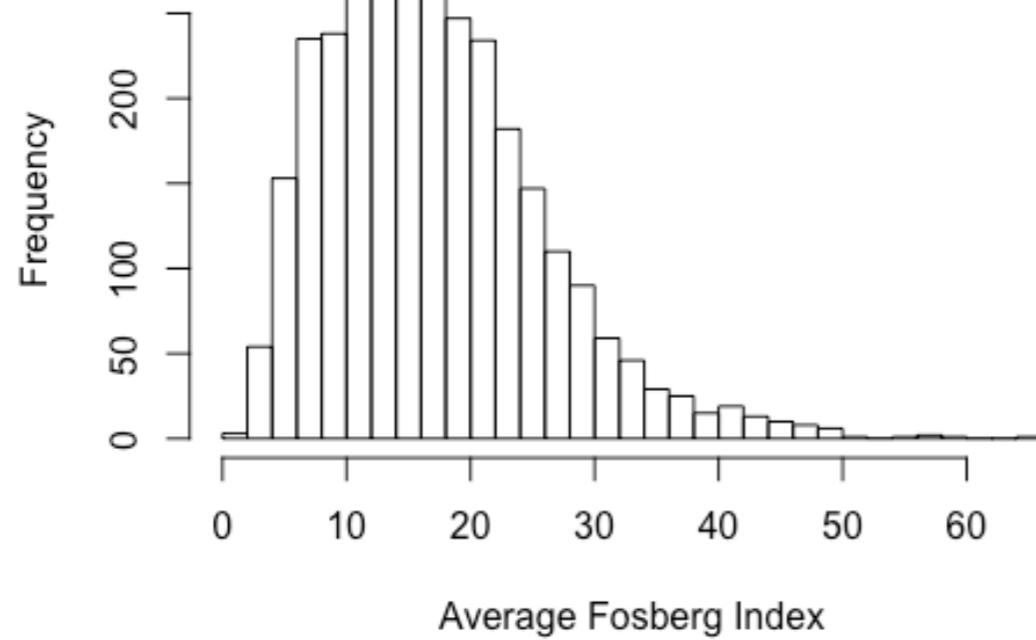
Average Temperature Box Plot



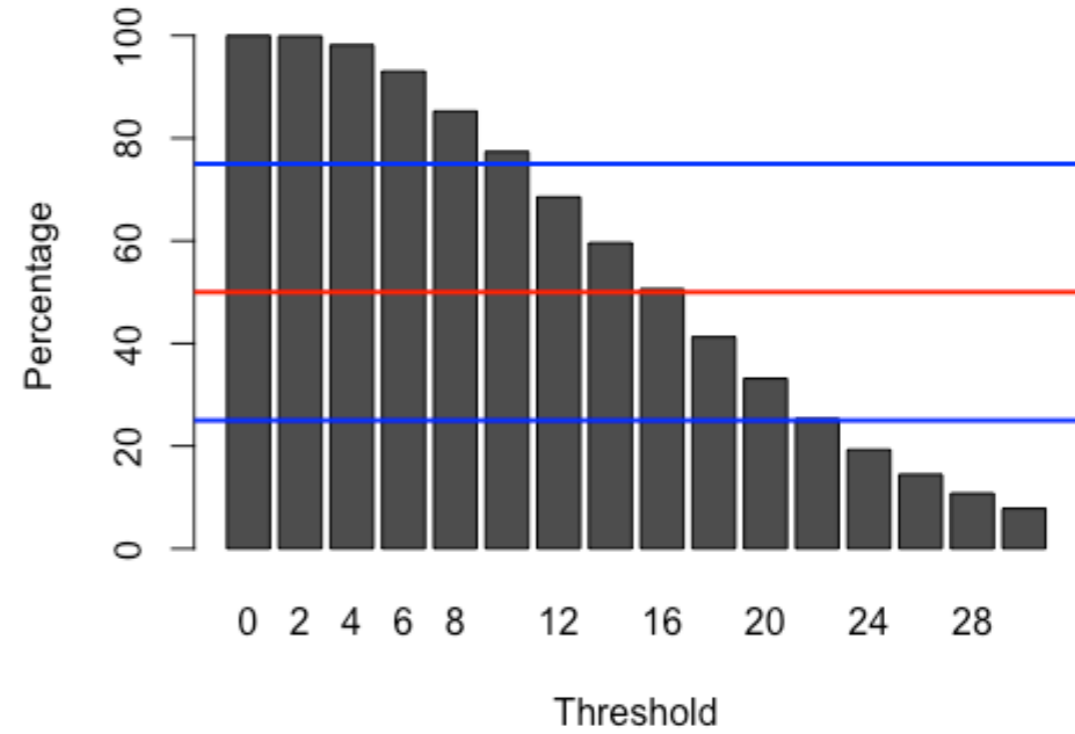
- Negatively-skewed (favorable) distribution
- However, such temperatures are frequently observed

Fosberg Index

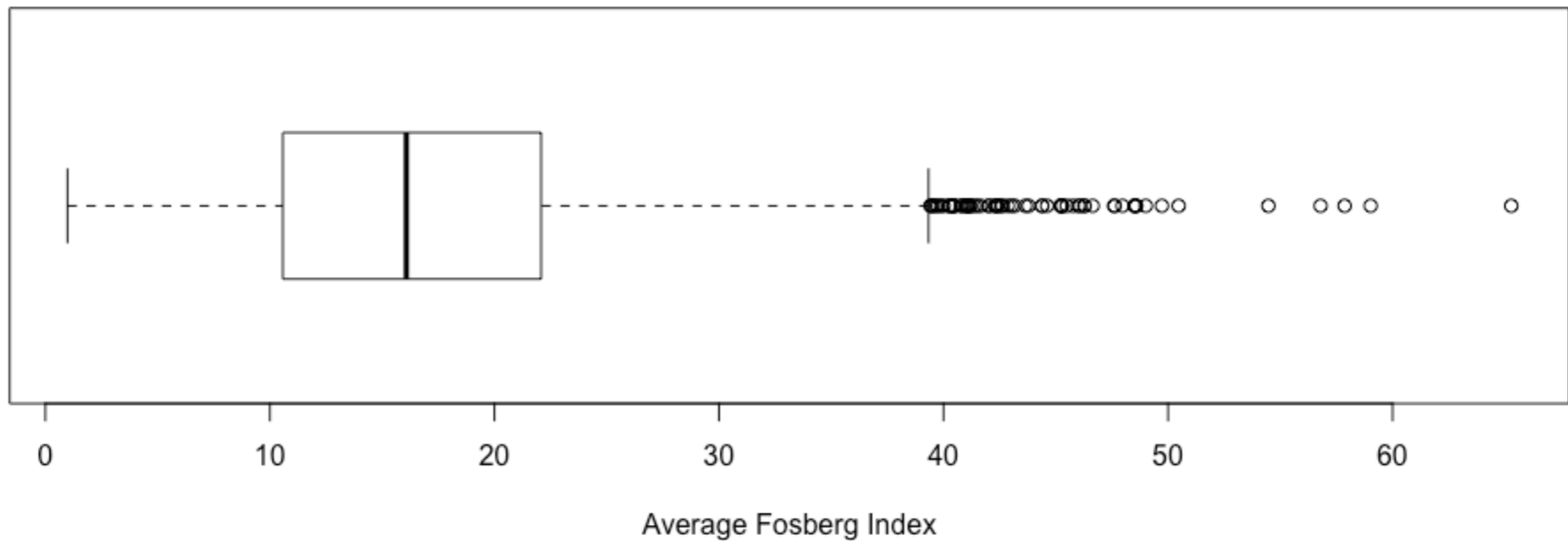
Average Fosberg Index Histogram



Percentile Plot of Average Fosberg Index

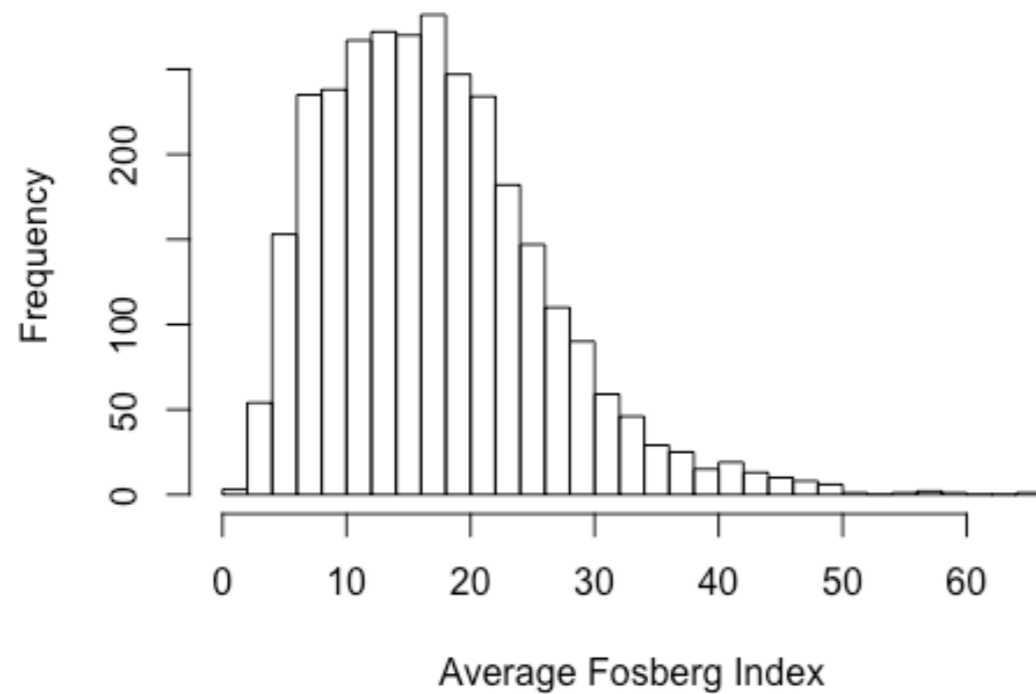


Average Fosberg Index Box Plot

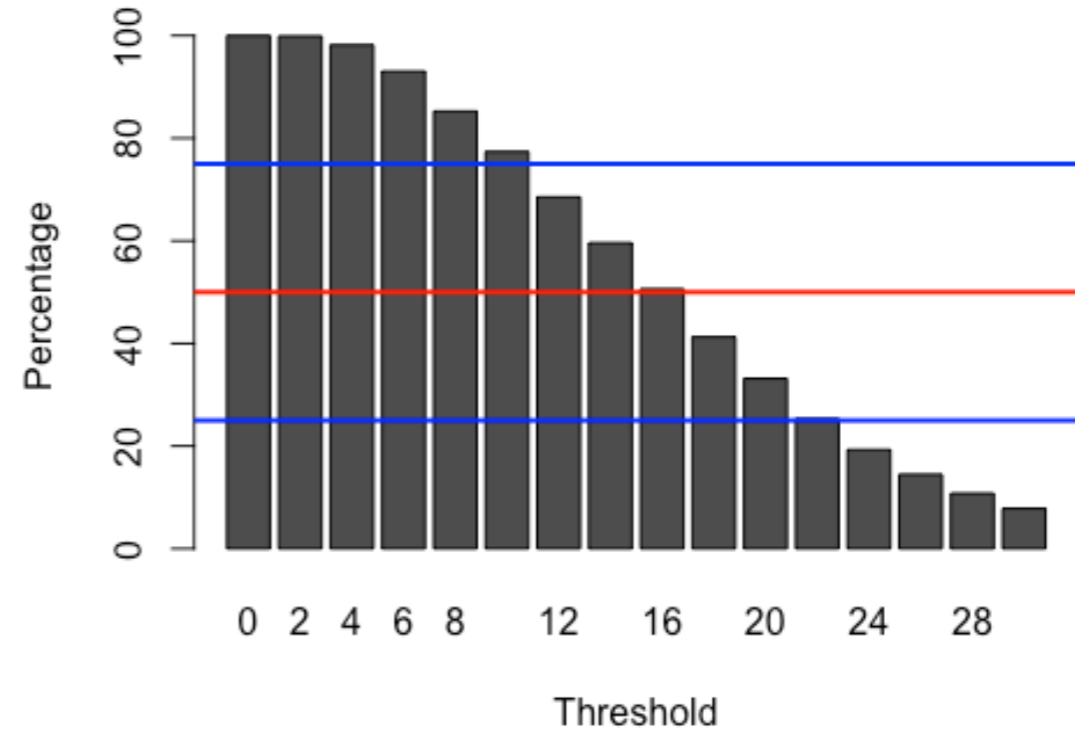


Fosberg Index

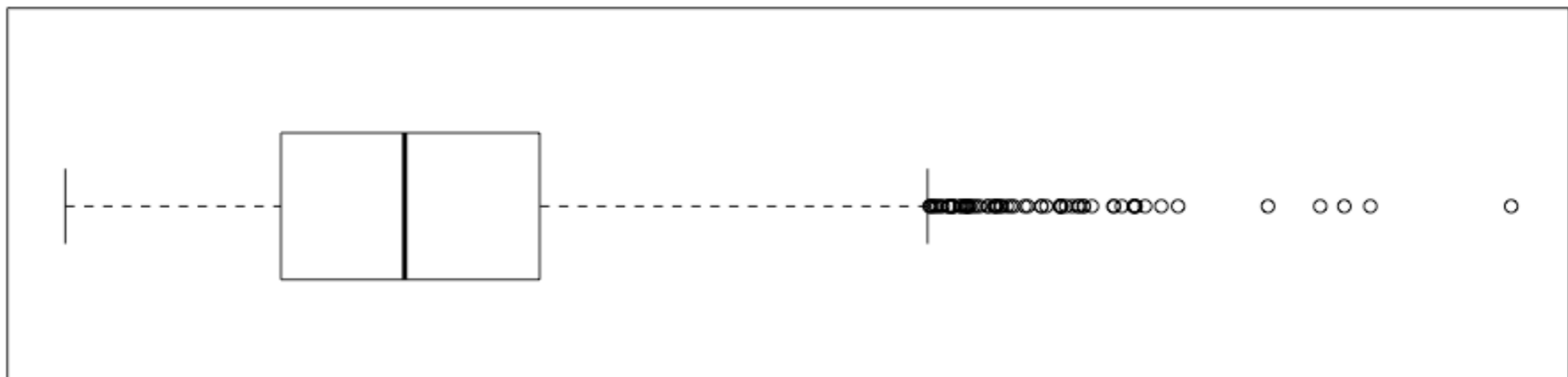
Average Fosberg Index Histogram



Percentile Plot of Average Fosberg Index



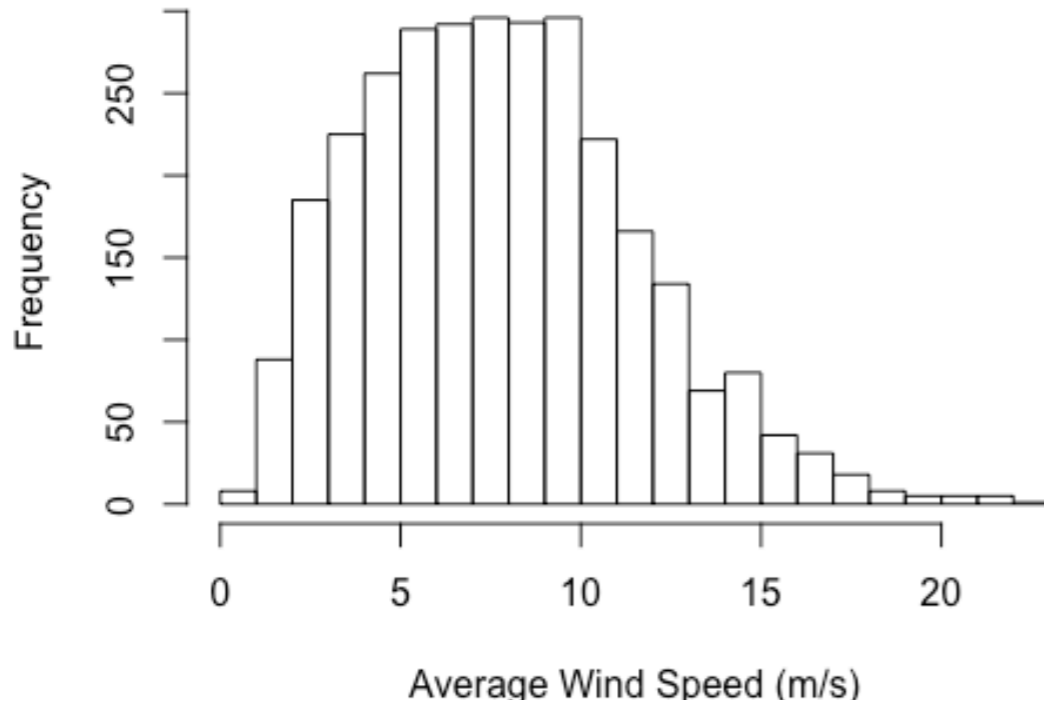
Average Fosberg Index Box Plot



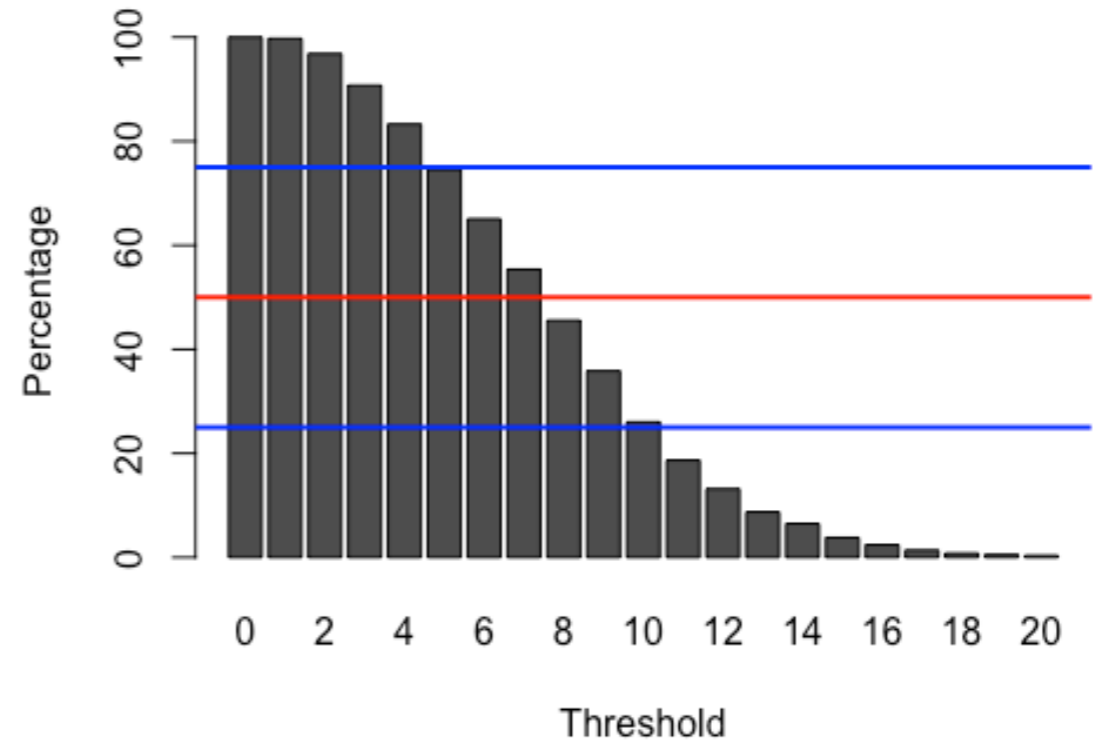
- Positively-skewed (unfavorable) distribution
- Less than 1% of all fires had Fosberg indices above 50

Wind Speed

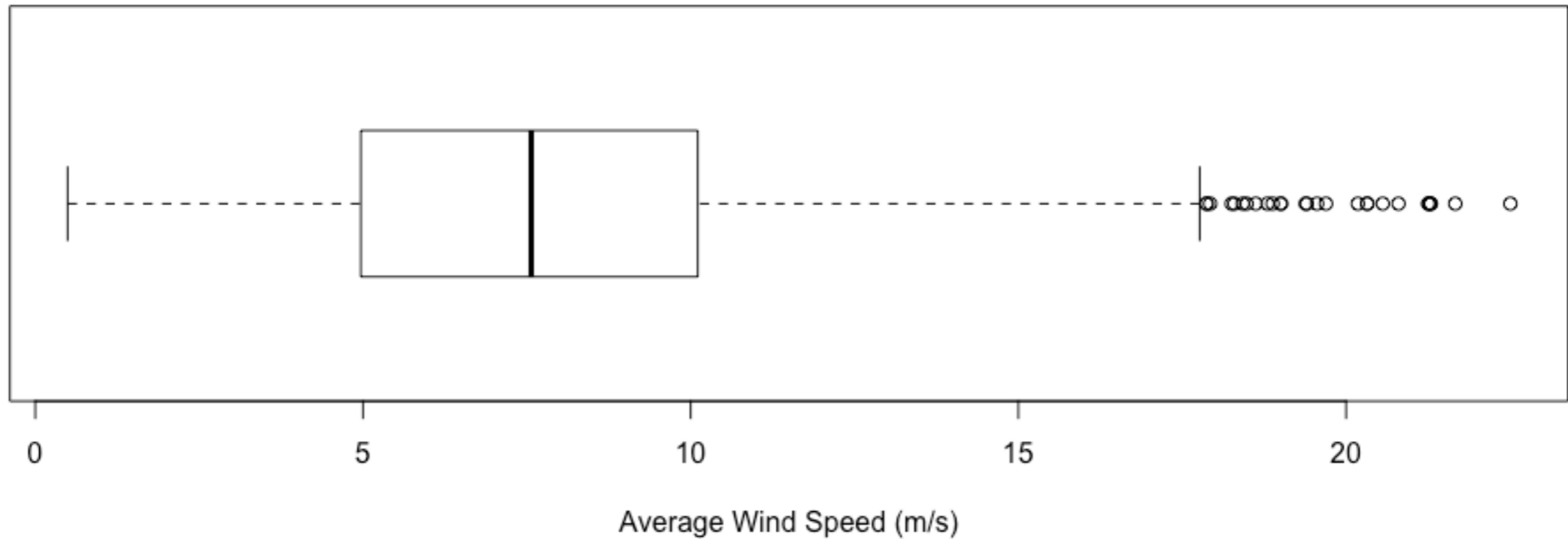
Average Wind Speed Histogram



Percentile Plot of Wind Speed

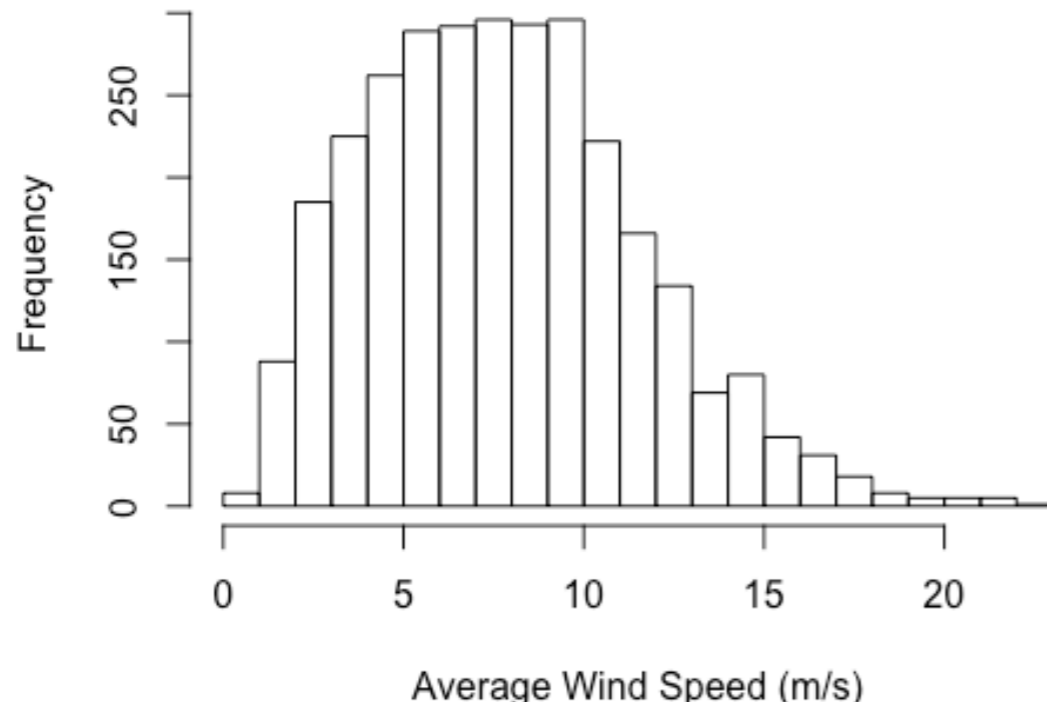


Average Wind Speed Box Plot

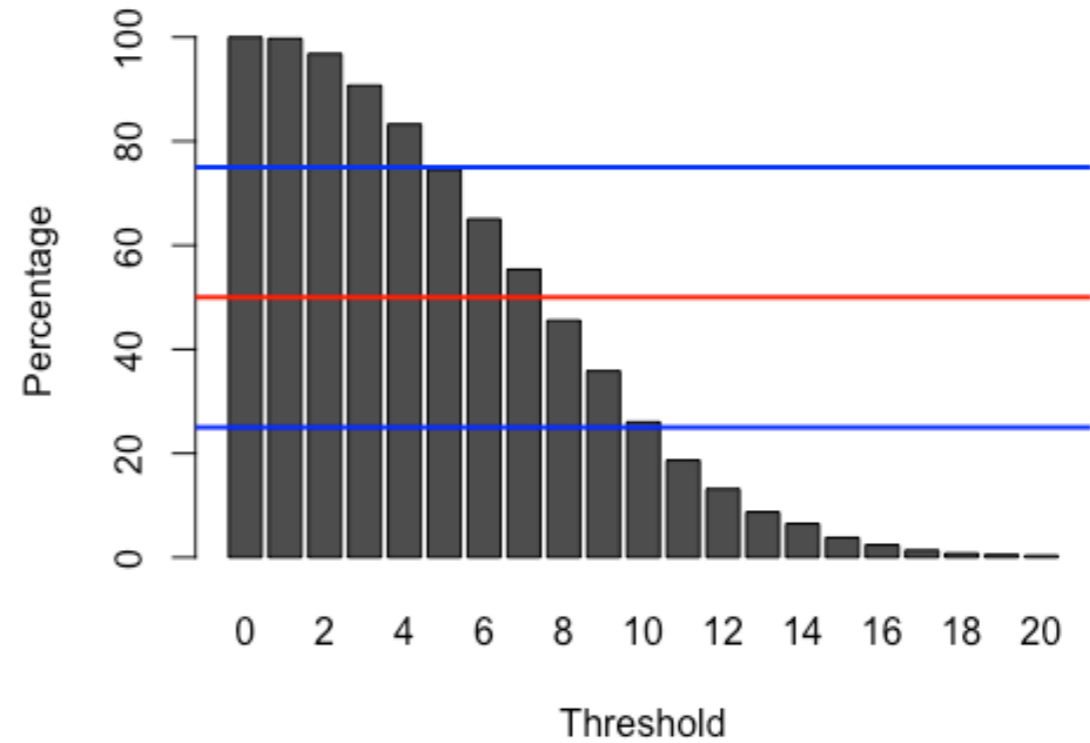


Wind Speed

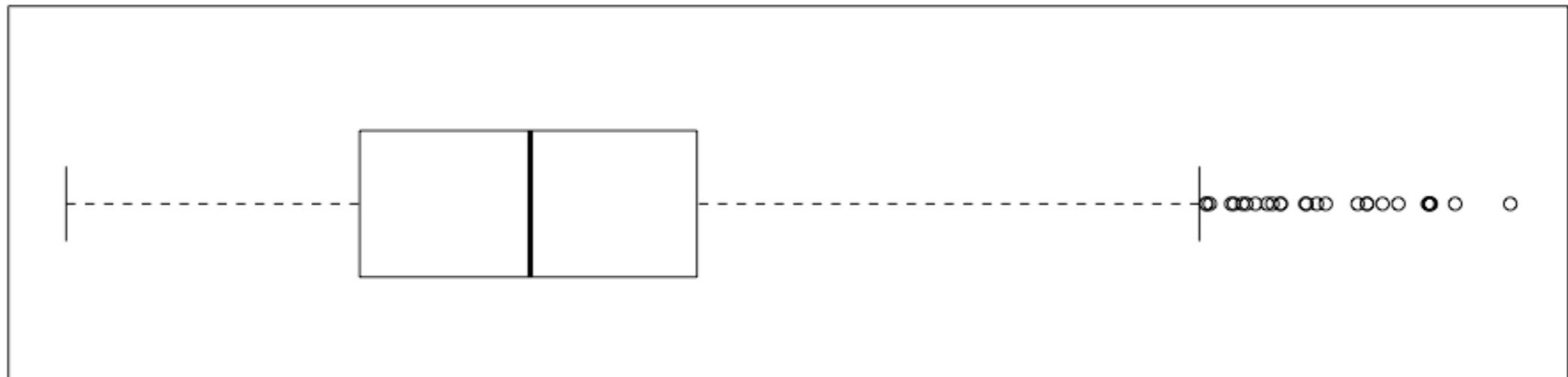
Average Wind Speed Histogram



Percentile Plot of Wind Speed



Average Wind Speed Box Plot

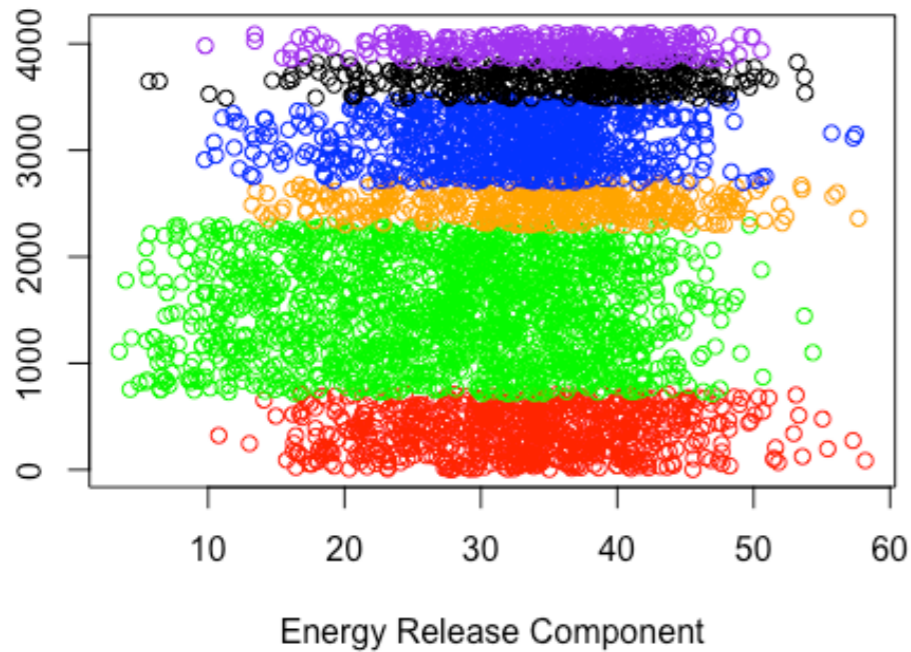


- Positively-skewed (unfavorable) distribution
- 75% of all fires occurred with wind speeds over 5 m/s (11 mph)

Environmental Parameters as a Predictor

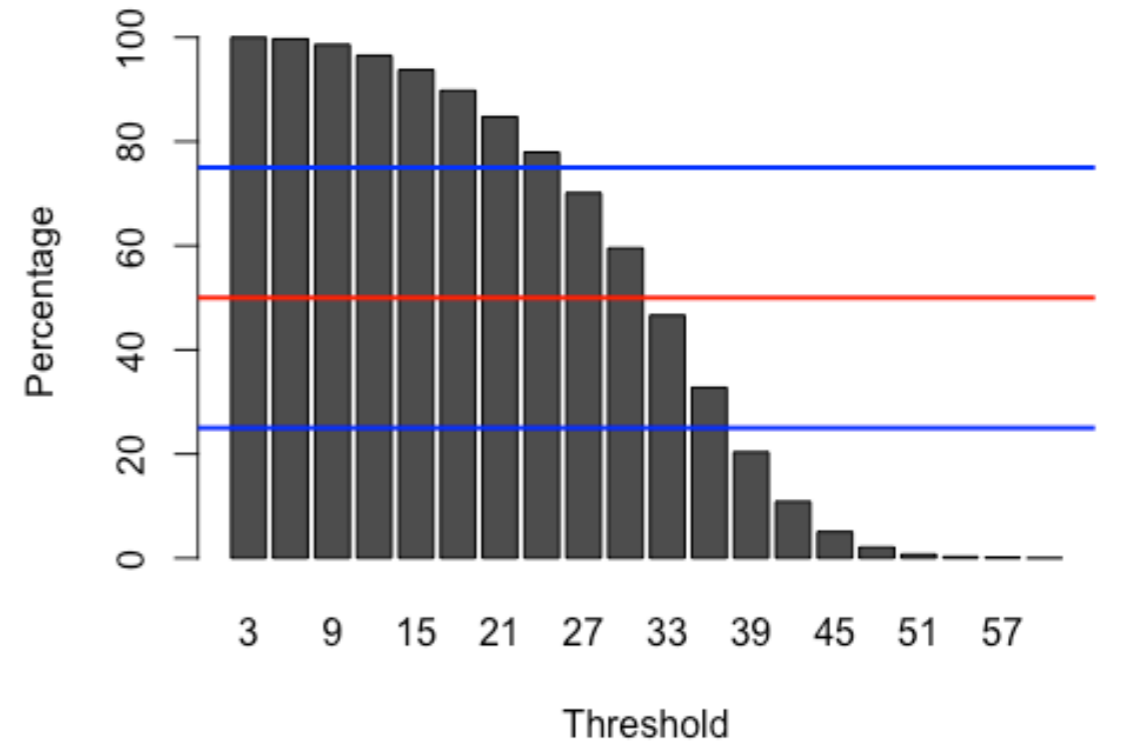
- No single environmental parameter appears to be a reliable predictor
- Suggests wildfires are more driven by fuels
- Can fuel parameters be used as a predictor?

Energy Release Component

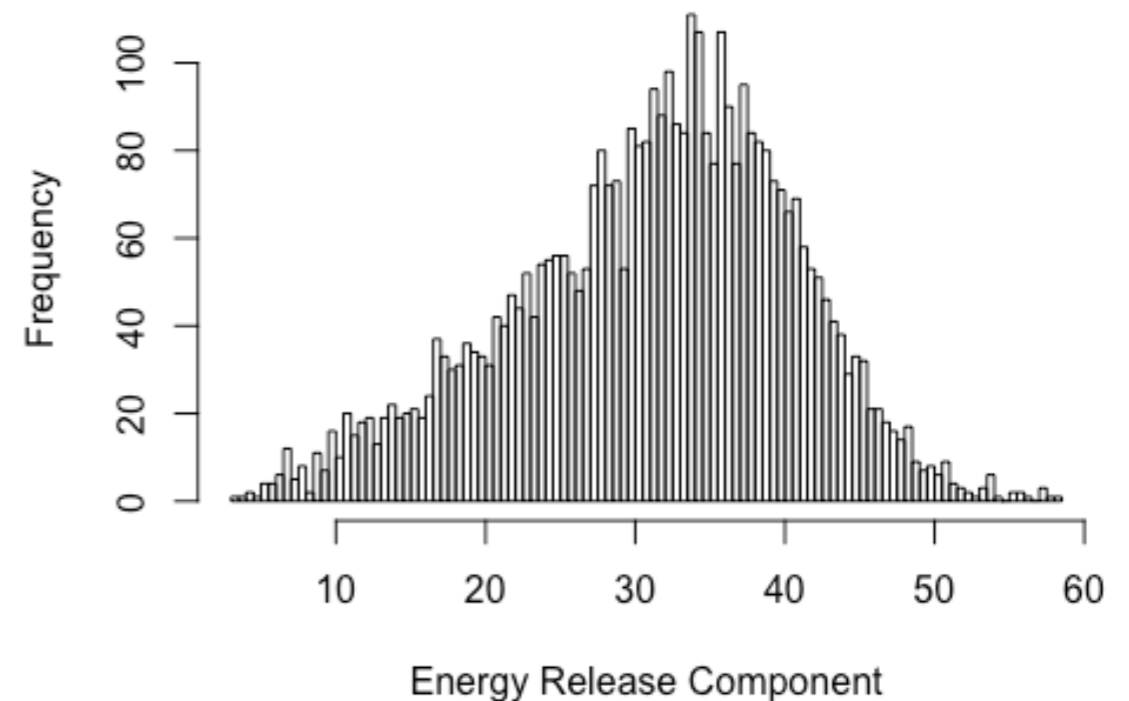


South Carolina
North Carolina
Mississippi
Georgia
Florida
Alabama

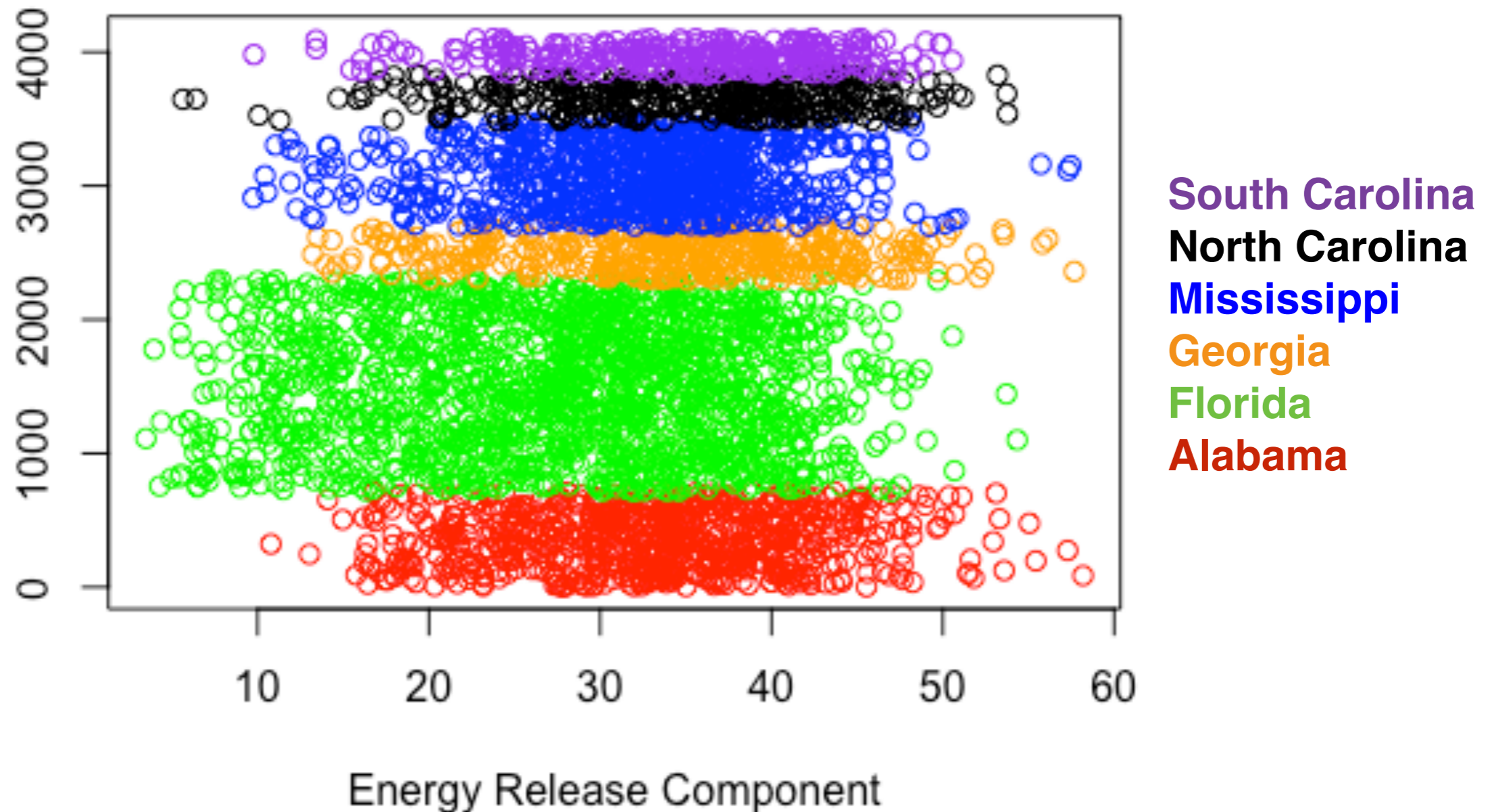
Percentile Plot of Energy Release Component



Histogram of Energy Release Component

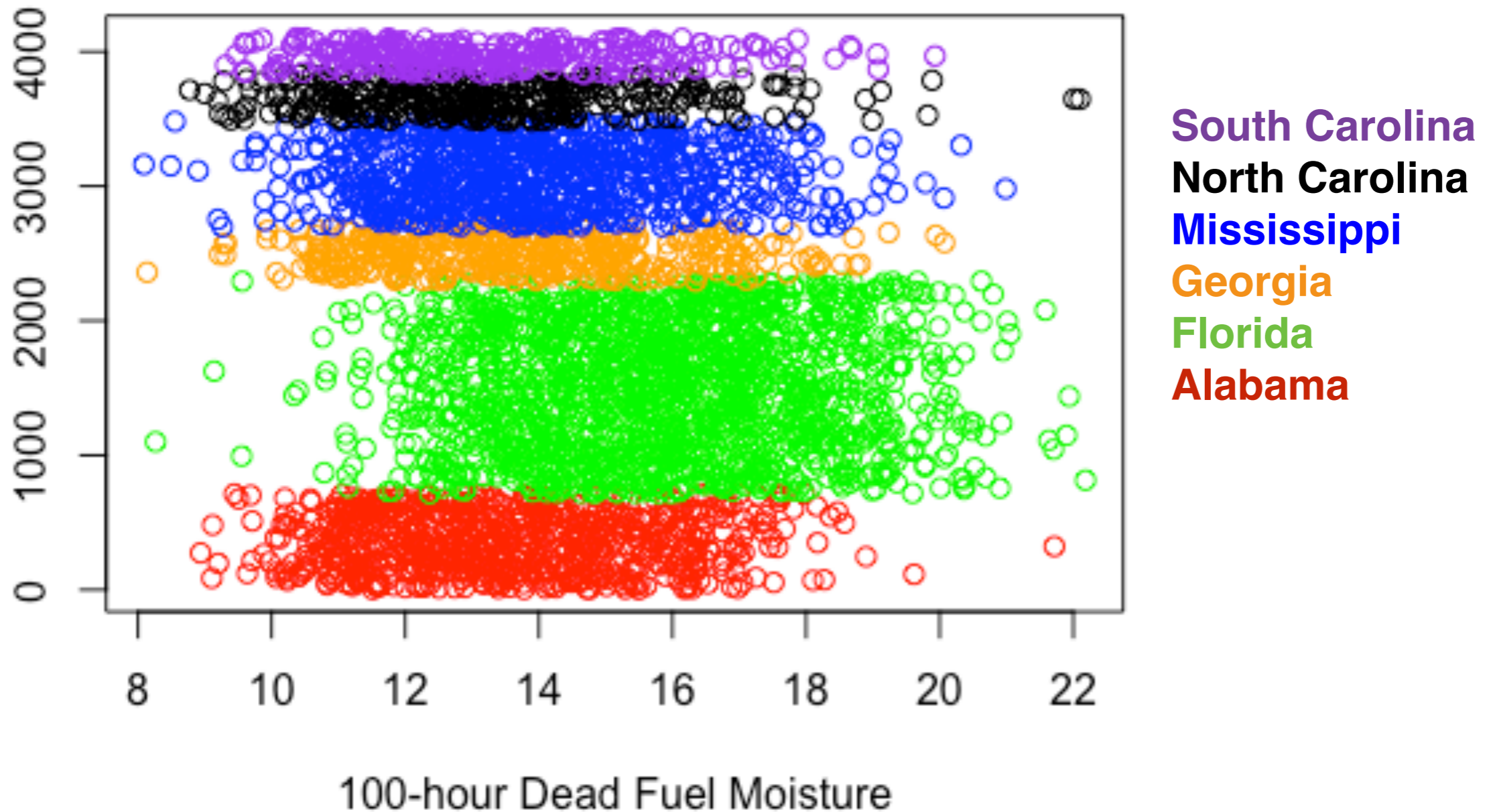


Energy Release Component



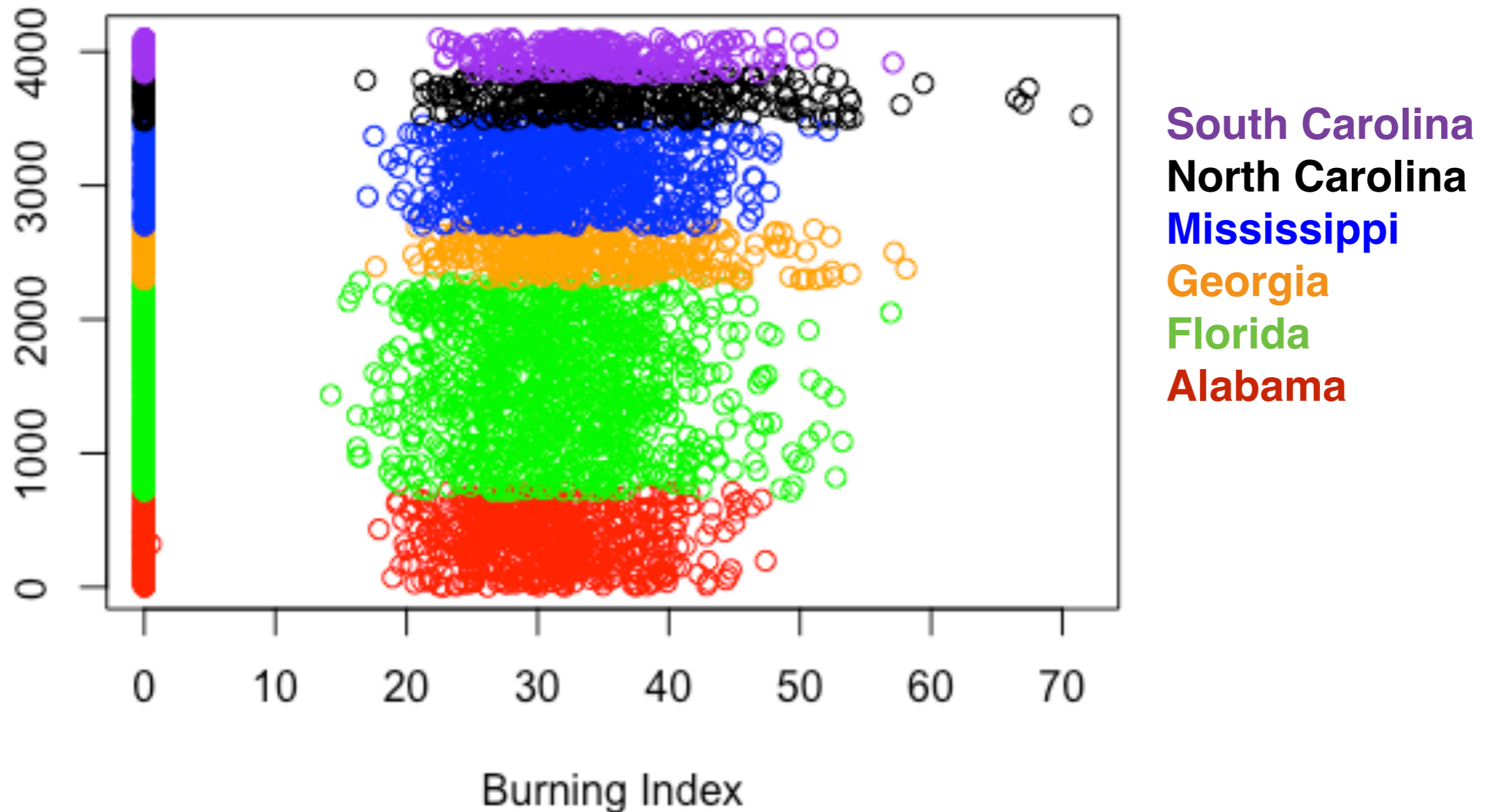
- Significant discrepancy between Florida and other states
- Majority of fires in Florida, fewest in the Carolinas and Georgia

100-Hour Dead Fuel Moisture



- Again, significant discrepancy between Florida and other states
- Majority of fires fall between 14% and 18% in Florida
- Majority of fires fall between 12% and 16% in other states

Burning Index



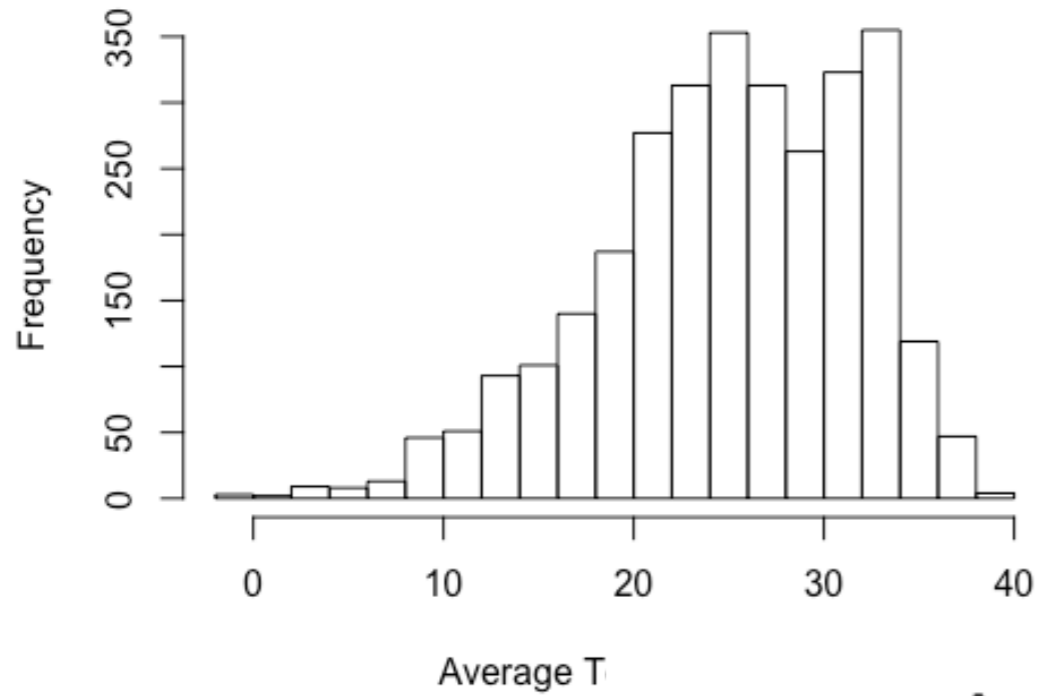
- Several burning indices close to 0
- Not every fire weather event is going to have a burning index

Fuel Parameters as a Predictor

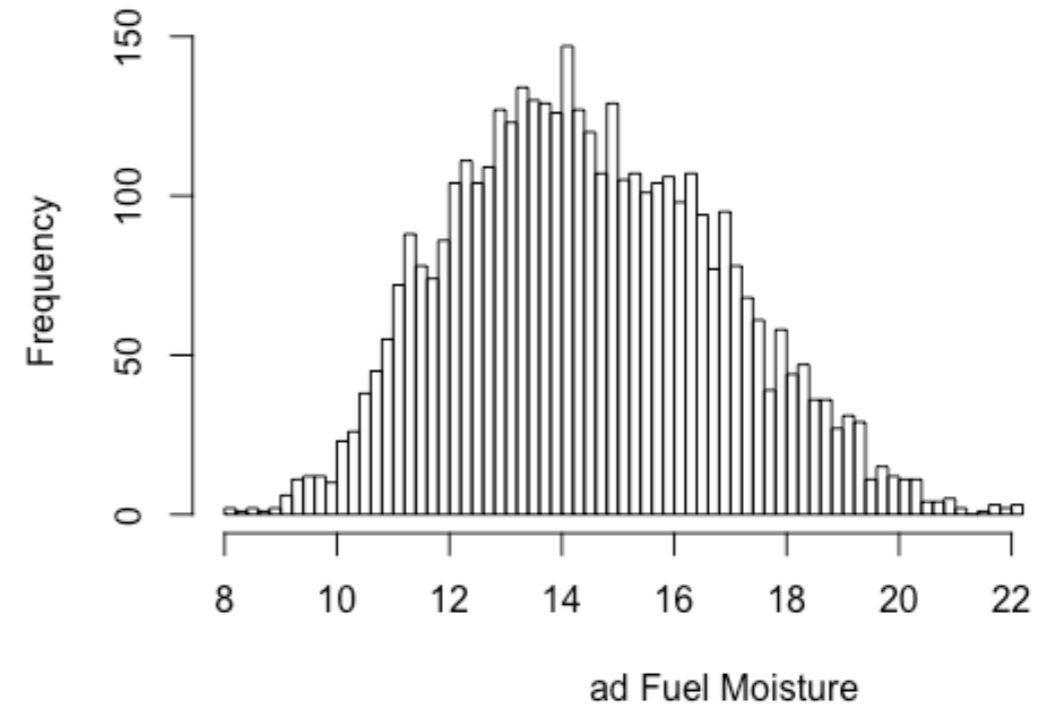
- Fuel parameters show slightly more favorable distributions
- Fires still occur under a wide range of values
- Some combination of parameters is needed to obtain a reliable predictor
- Combinations of parameters analyzed in two ways:
 - Combining two or more parameters together mathematically (multiplication and division)
 - Checking what percentage of fires fell under a set of criteria (Example: How many fires had a temperature over 70°F and a wind speed over 5 m/s?)

Temperature ÷ 100-Hour Fuel Moisture

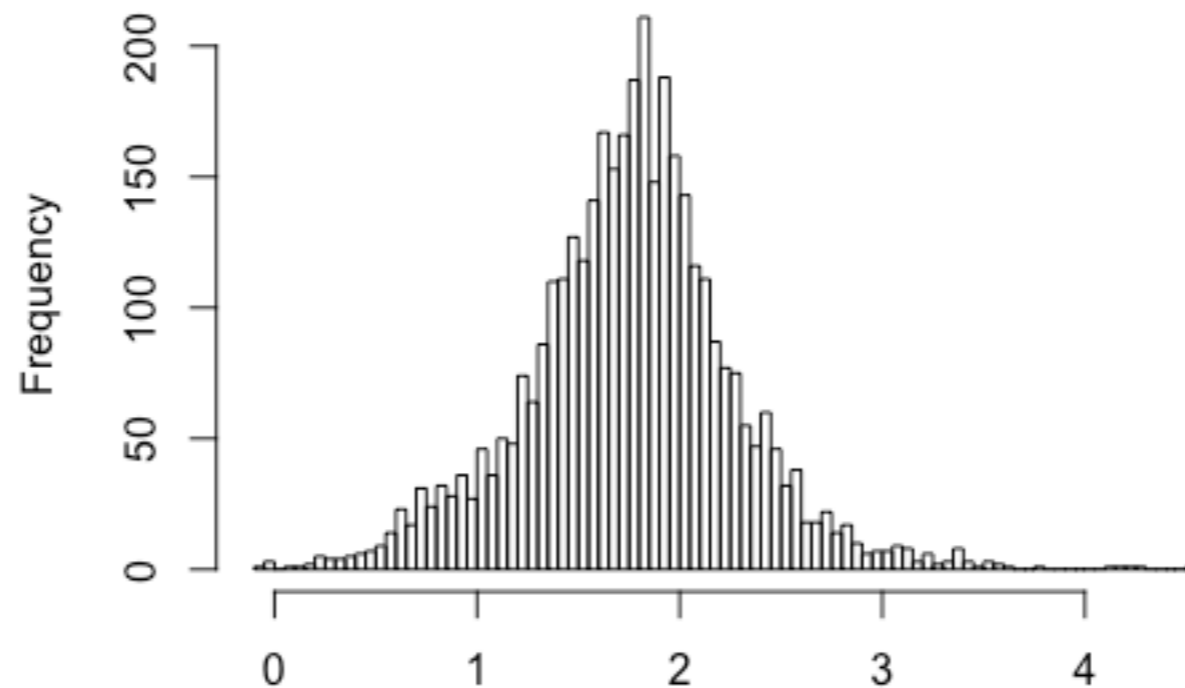
Average Temperature Histogram



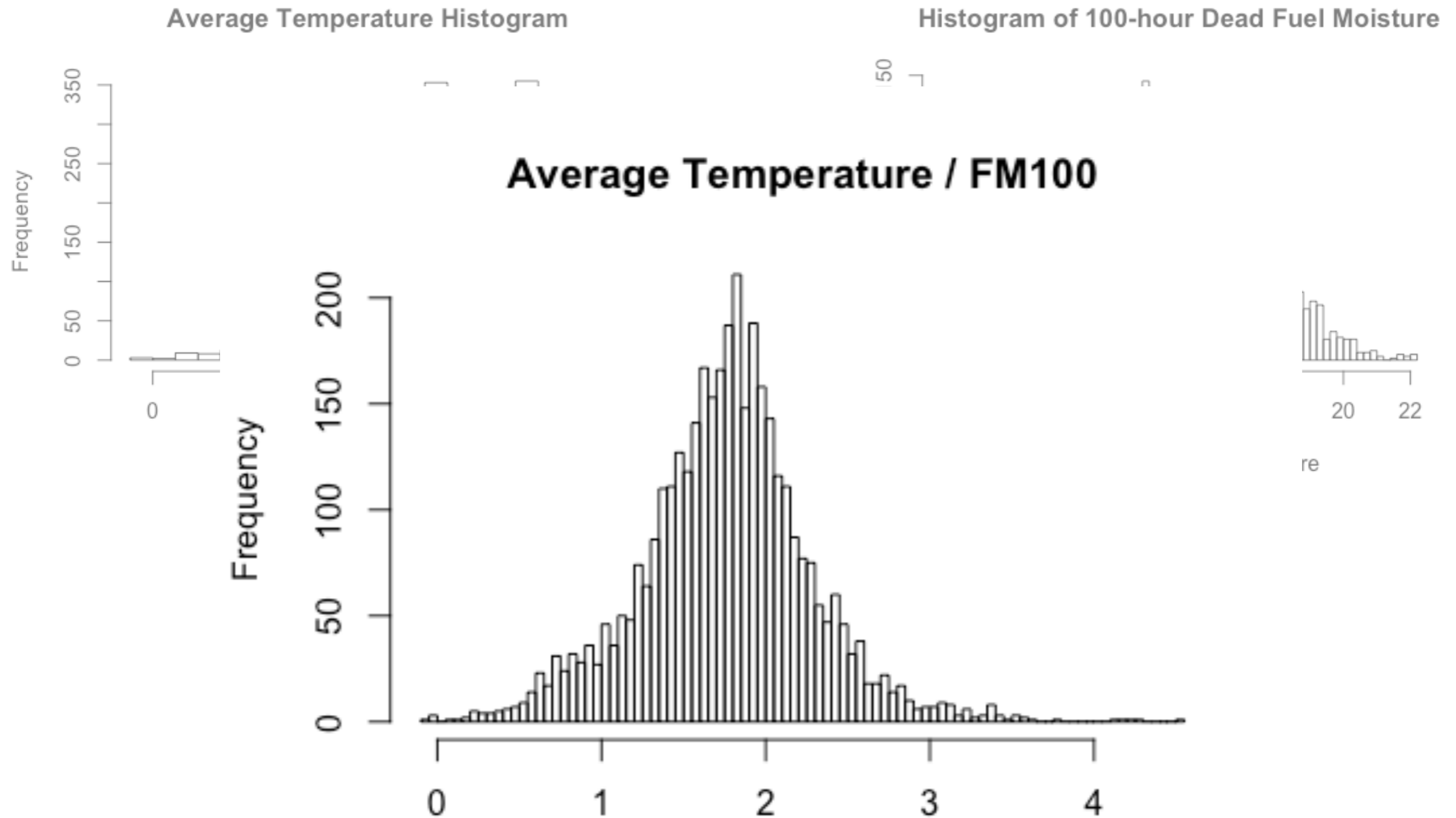
Histogram of 100-hour Dead Fuel Moisture



Average Temperature / FM100

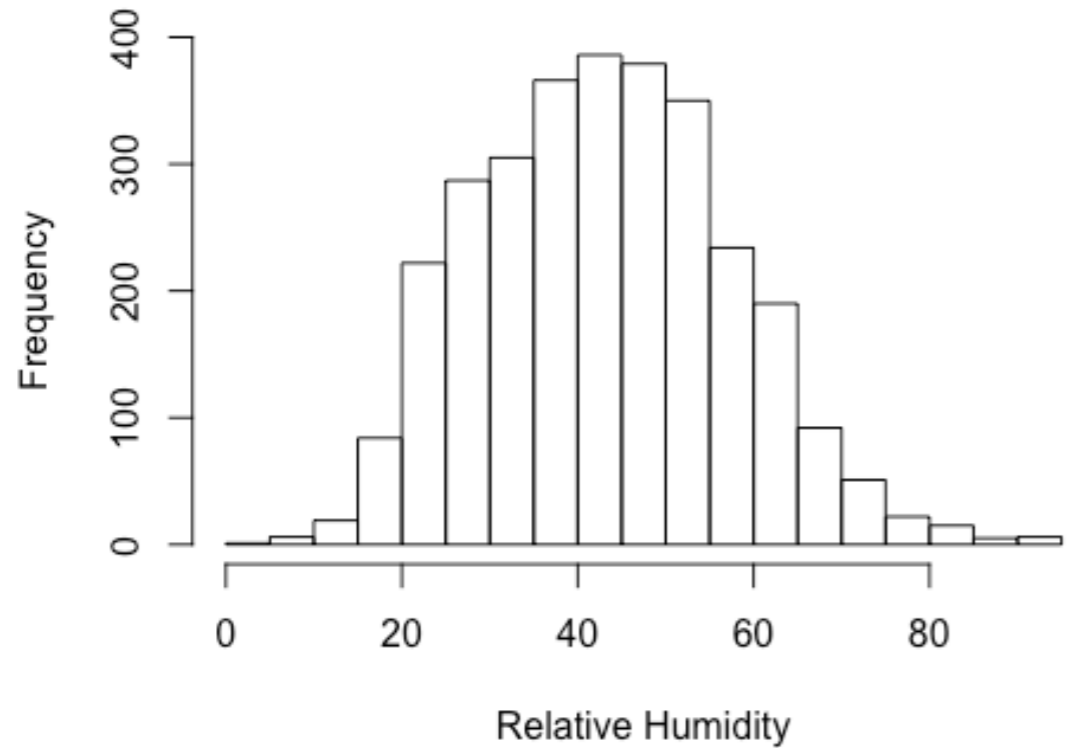


Temperature \div 100-Hour Fuel Moisture

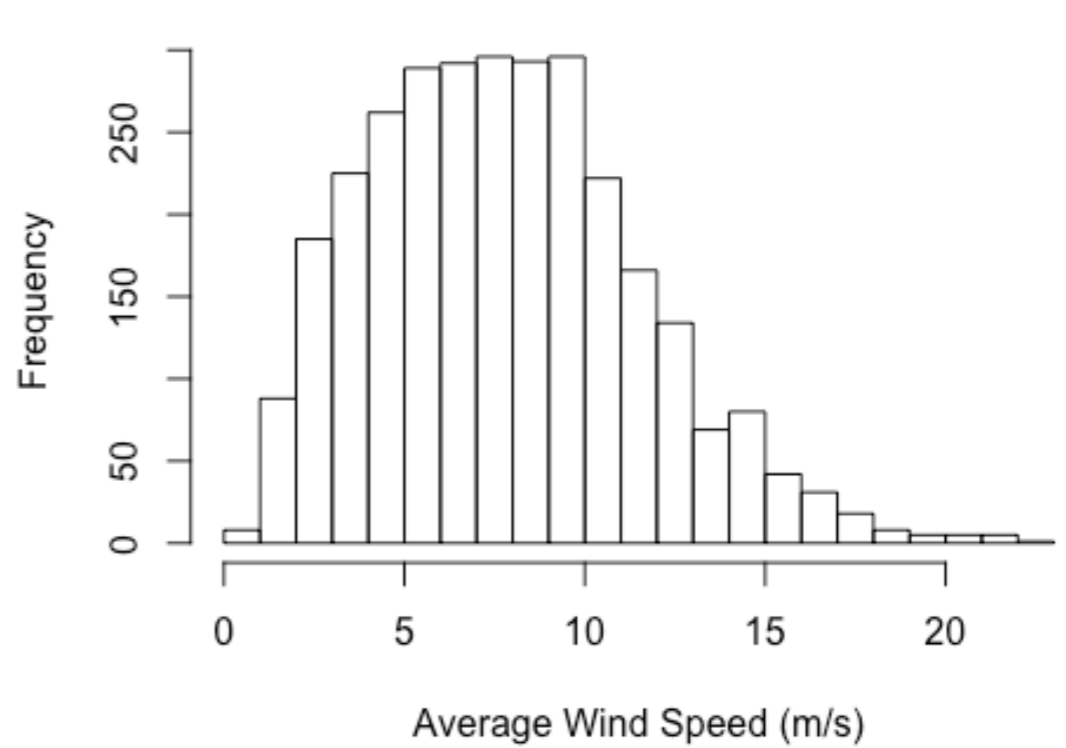


- Temperature and 100-hr distributions were originally broad
- Distribution becomes narrow when combined in this way

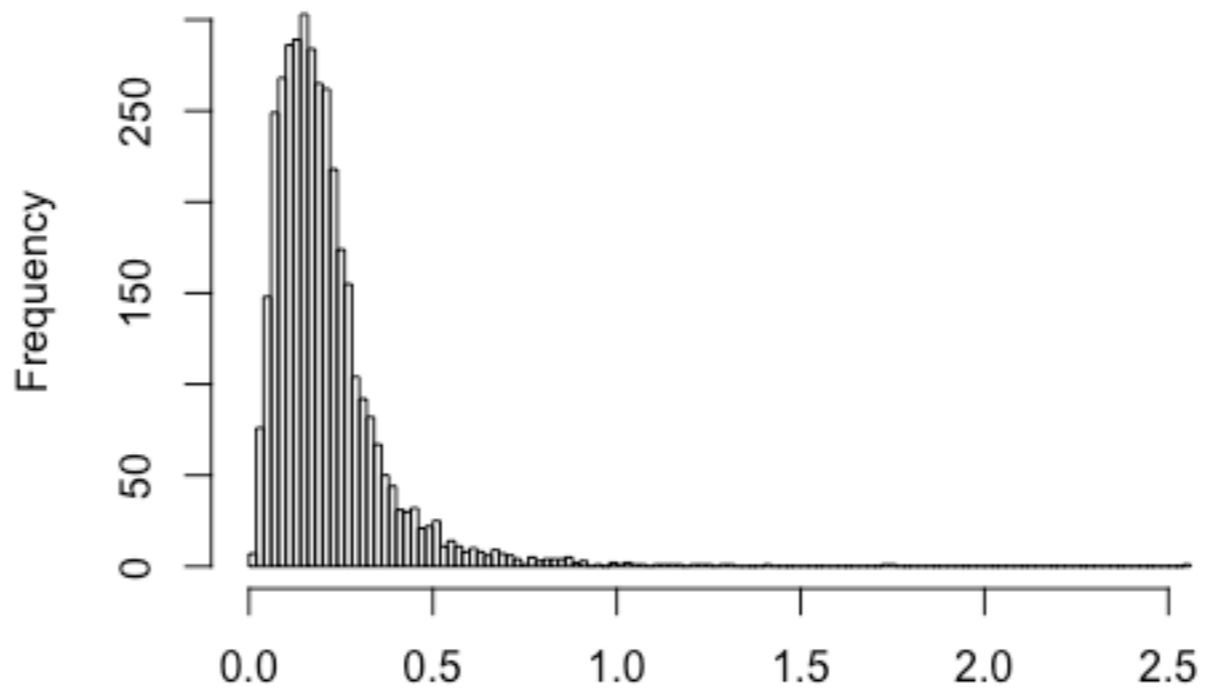
Average Relative Humidity Histogram



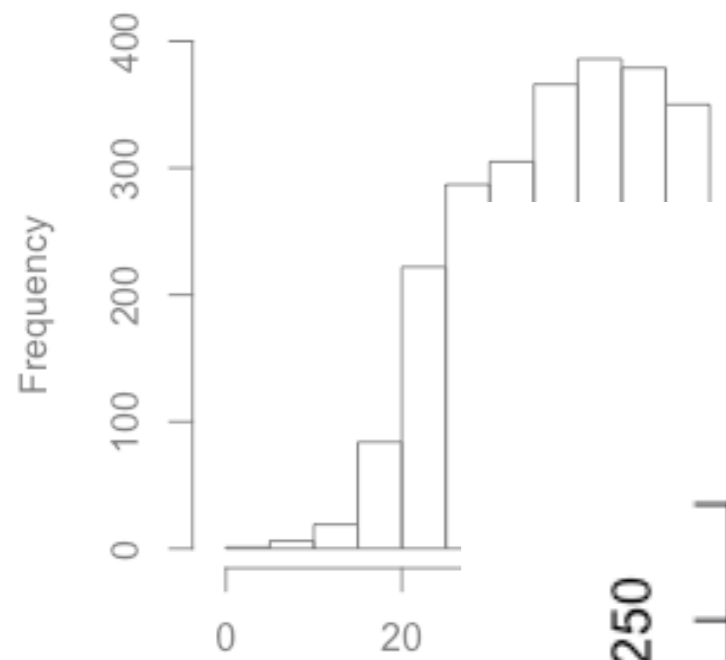
Average Wind Speed Histogram



Average Wind Speed / Average RH



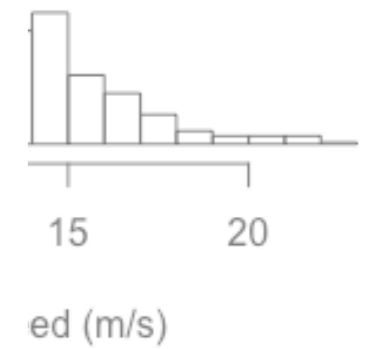
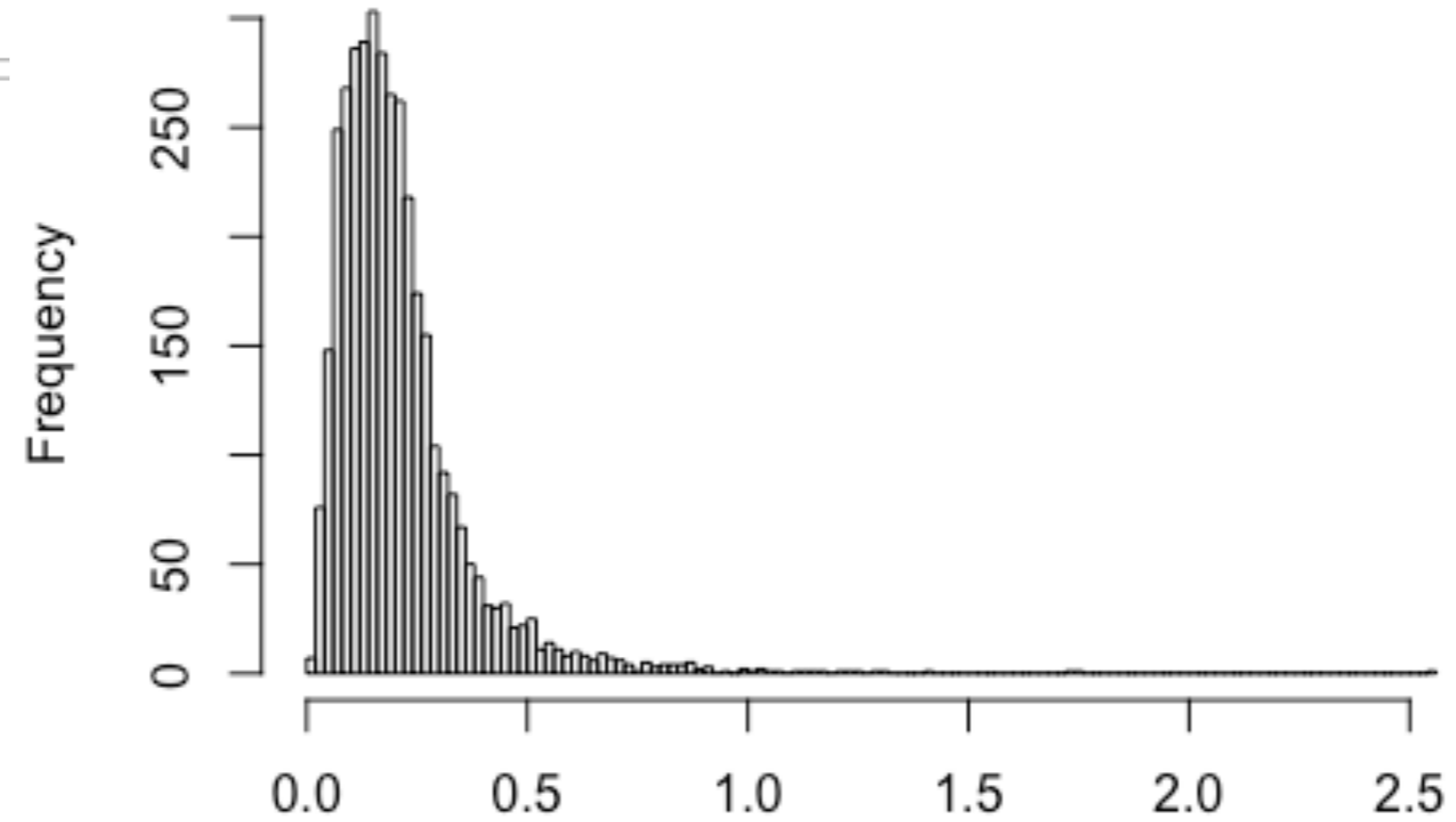
Average Relative Humidity Histogram



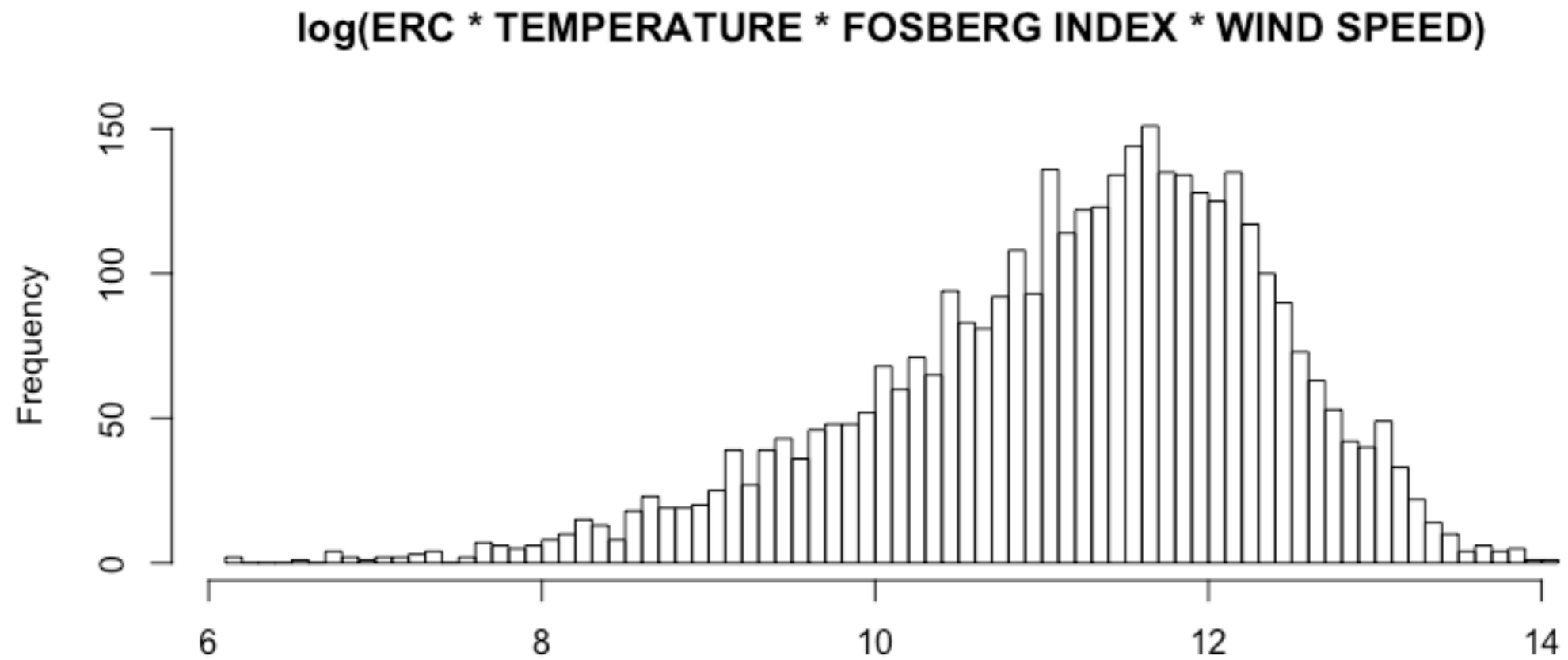
Average Wind Speed Histogram



Average Wind Speed / Average RH

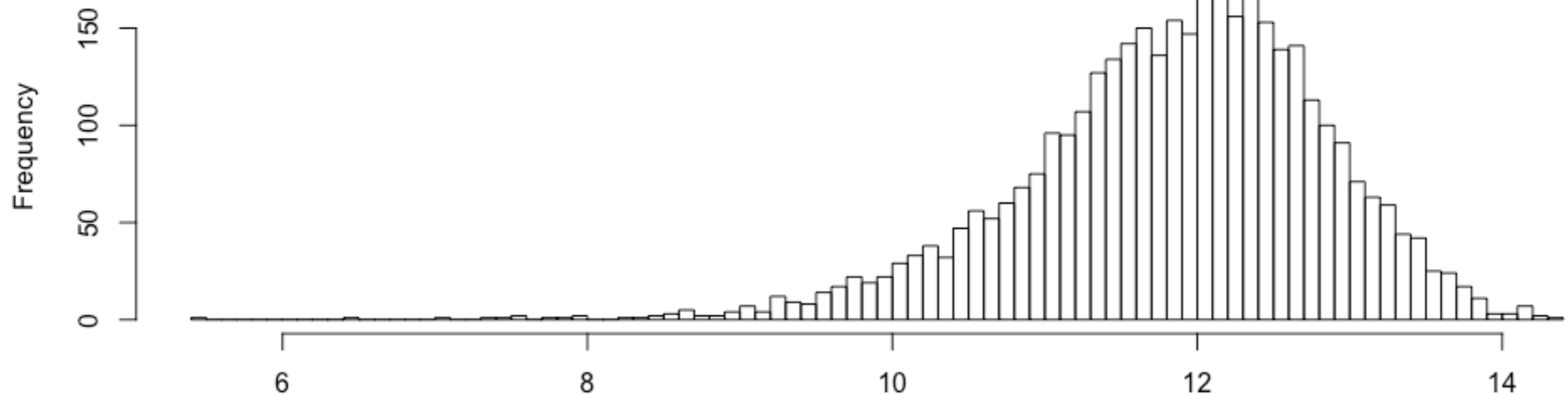


- Narrow, but positively-skewed distribution
- Again, distributions become narrow when combined this way



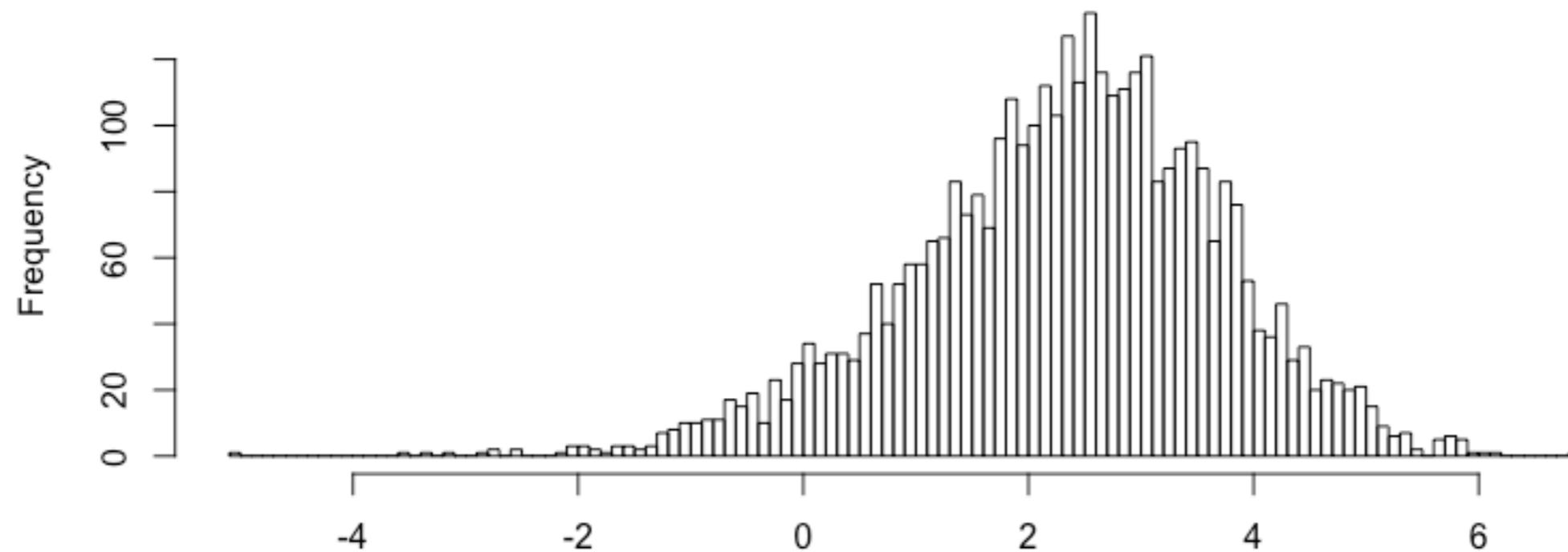
- Negatively-skewed (favorable)
- Plotted on a logarithmic scale (hence the log in the equation)

$\log(\text{ERC} * \text{TEMPERATURE} * \text{FOSBERG INDEX} * (\text{TEMPERATURE} - \text{DEWPOINT}))$



- Negatively-skewed (favorable)
- Plotted on a logarithmic scale (hence the log in the equation)

$\log(\text{ERC} * (\text{TEMPERATURE} - \text{DEWPOINT}) * \text{FOSBERG INDEX} / (\text{RH} * \text{FM100}))$



- Negatively-skewed (favorable)
- Plotted on a logarithmic scale (hence the log in the equation)

Second Bivariate Method

- Cells highlighted **green** are where an algorithm detected a significant “jump” while still “catching” at least 50% of the fires
- Cells highlighted **yellow** are where an algorithm detected a significant “jump”, but without “catching” a majority of the fires
- Cutoff values are obtained by finding the most favorable value while still maintaining several green cells (minimize FAR)

Process Continued For All Combinations

Arrived at the following cutoff values (outside of Florida):

Temperature > 75 °F

Relative Humidity < 40 %

100-hr Fuel Moisture < 16 %

ERC > 30

Wind speed > 11 mph

* Fosberg Index not included for the criteria due to having a largely unfavorable distribution

* Require at least 3 of these criteria be met to issue a critical risk

Process Continued For All Combinations

Arrived at the following cutoff values (in Florida):

Temperature > 77 °F

Relative Humidity < 50 %

100-hr Fuel Moisture < 18 %

ERC > 25

Wind speed > 11 mph

Probability of thunderstorms > 40 %

* Fosberg Index not included for the criteria due to having a largely unfavorable distribution

* Require at least 4 of these criteria be met to issue a critical risk

Example Case Revisited With New Criteria

At least 3 of the following 5 criteria:






Temperature > 75 °F

Relative Humidity < 40 %

100-hr Fuel Moisture < 16 %

ERC > 30

Wind speed > 11 mph

Afternoon surface temperature:	79 °F	
Minimum relative humidity:	26 %	
Maximum wind speed:	16 mph	
Energy release component:	35	
100-hour fuel moisture:	16.3%	

Another Case (5000-acre fire)

At least 3 of the following 5 criteria:






Temperature > 75 °F

Relative Humidity < 40 %

100-hr Fuel Moisture < 16 %

ERC > 30

Wind speed > 11 mph

Afternoon surface temperature:	87 °F	
Minimum relative humidity:	31 %	
Maximum wind speed:	21 mph	
Energy release component:	30	
100-hour fuel moisture:	15.7%	

A Third Case (100-acre fire)

At least 3 of the following 5 criteria:






Temperature > 75 °F

Relative Humidity < 40 %

100-hr Fuel Moisture < 16 %

ERC > 30

Wind speed > 11 mph

Afternoon surface temperature:	58 °F	
Minimum relative humidity:	32 %	
Maximum wind speed:	18 mph	
Energy release component:	32	
100-hour fuel moisture:	12.1%	

Example Florida Case (8100-acre fire)

At least 4 of the following 6 criteria:

Temperature > 77 °F







Relative Humidity < 50 %

100-hr Fuel Moisture < 18 %

ERC > 25

Wind speed > 11 mph







Thunderstorm Probability > 40 %

Afternoon surface temperature:	87 °F	
Minimum relative humidity:	49 %	
Maximum wind speed:	18 mph	
Energy release component:	18	
100-hour fuel moisture:	17.3%	
Thunderstorm probability:	10 % - 40 %	

Another Example Florida Case (1294-acre fire)

At least 4 of the following 6 criteria:

- Temperature > 77 °F
- Relative Humidity < 50 %
- 100-hr Fuel Moisture < 18 %
- ERC > 25
- Wind speed > 11 mph
- Thunderstorm Probability > 40 %

Afternoon surface temperature:	68 °F	
Minimum relative humidity:	57 %	
Maximum wind speed:	33 mph	
Energy release component:	27	
100-hour fuel moisture:	14.5%	
Thunderstorm probability:	< 10 %	

Conclusions

Summarized Findings

- Fire weather “season” in late winter/early spring
- More fires occur in Florida than other states
- Significant number of fires in Florida driven by lightning
- Critical fire weather criteria heavily dependent on fuels
- Fire weather criteria in Florida different than other states

Conclusions

Topics Not Addressed

- Influences of ENSO on severity of fire season
- Behavior of the regional plantation when subjected to extreme stresses (drought, extreme cold, extreme heat)
- Climatology of each parameter
- Composite parameters were formulated, but not extensively tested

Conclusion

Potential Issues With New Forecasting Criteria

- False alarm rate?
- Which thresholds could be relaxed?
 - Ex: Should a forecaster pay less attention to fuel moisture if the temperature is extremely high or vice versa?
- Predictability?
 - Fires are largely fuel driven, fuel behavior is difficult to predict

Questions?

Second Bivariate Method

100-Hour Fuel Moisture vs Temperature

- 100-hour fuel moisture cutoff value around 16%

		Temperature (°C)																			
		0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	34.0	36.0	38.0
F M 1 0 0	10.0	1.5	1.5	1.5	1.5	1.5	1.5	1.44	1.44	1.31	1.2	1.1	1.04	0.83	0.69	0.51	0.37	0.29	0.24	0.08	0.03
	12.0	15.71	15.68	15.65	15.52	15.49	15.33	14.98	14.64	13.94	12.66	11.32	9.64	7.32	5.53	3.74	2.46	1.76	1.44	0.67	0.21
	14.0	44.87	44.82	44.68	44.5	44.42	43.86	42.92	41.75	40.17	37.13	34.27	29.59	23.72	17.76	11.99	8.41	5.9	3.79	1.6	0.48
	16.0	72.97	72.89	72.65	72.41	72.17	71.26	70.03	68.32	66.11	62.34	58.28	51.23	42.52	33.41	23.77	17.01	11.51	5.9	2.14	0.64
	18.0	91.99	91.91	91.67	91.4	91.08	90.12	88.78	86.57	83.81	79.51	74.84	66.37	56.49	45.62	33.95	24.6	16.48	7.83	2.43	0.67
	20.0	98.96	98.88	98.64	98.34	98.02	97.04	95.49	93.06	90.09	85.63	80.8	72.12	61.91	50.51	38.38	27.96	18.27	8.15	2.43	0.67
	22.0	99.92	99.84	99.6	99.31	98.99	98.0	96.45	94.02	91.03	86.51	81.65	72.97	62.77	51.28	39.08	28.47	18.56	8.17	2.46	0.67
	24.0	100.0	99.92	99.68	99.39	99.07	98.08	96.53	94.1	91.11	86.57	81.7	73.02	62.82	51.34	39.13	28.5	18.59	8.17	2.46	0.67
	26.0	100.0	99.92	99.68	99.39	99.07	98.08	96.53	94.1	91.11	86.57	81.7	73.02	62.82	51.34	39.13	28.5	18.59	8.17	2.46	0.67
	28.0	100.0	99.92	99.68	99.39	99.07	98.08	96.53	94.1	91.11	86.57	81.7	73.02	62.82	51.34	39.13	28.5	18.59	8.17	2.46	0.67
	30.0	100.0	99.92	99.68	99.39	99.07	98.08	96.53	94.1	91.11	86.57	81.7	73.02	62.82	51.34	39.13	28.5	18.59	8.17	2.46	0.67

Second Bivariate Method

100-Hour Fuel Moisture vs Temperature

- Again, temperature cutoff around 24°C (75°F)

		Temperature (°C)																			
		0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	34.0	36.0	38.0
F M 1 0 0	10.0	1.5	1.5	1.5	1.5	1.5	1.5	1.44	1.44	1.31	1.2	1.1	1.04	0.83	0.69	0.51	0.37	0.29	0.24	0.08	0.03
	12.0	15.71	15.68	15.65	15.52	15.49	15.33	14.98	14.64	13.94	12.66	11.32	9.64	7.32	5.53	3.74	2.46	1.76	1.44	0.67	0.21
	14.0	44.87	44.82	44.68	44.5	44.42	43.86	42.92	41.75	40.17	37.13	34.27	29.59	23.72	17.76	11.99	8.41	5.9	3.79	1.6	0.48
	16.0	72.97	72.89	72.65	72.41	72.17	71.26	70.03	68.32	66.11	62.34	58.28	51.23	42.52	33.41	23.77	17.01	11.51	5.9	2.14	0.64
	18.0	91.99	91.91	91.67	91.4	91.08	90.12	88.78	86.57	83.81	79.51	74.84	66.37	56.49	45.62	33.95	24.6	16.48	7.83	2.43	0.67
	20.0	98.96	98.88	98.64	98.34	98.02	97.04	95.49	93.06	90.09	85.63	80.8	72.12	61.91	50.51	38.38	27.96	18.27	8.15	2.43	0.67
	22.0	99.92	99.84	99.6	99.31	98.99	98.0	96.45	94.02	91.03	86.51	81.65	72.97	62.77	51.28	39.08	28.47	18.56	8.17	2.46	0.67
	24.0	100.0	99.92	99.68	99.39	99.07	98.08	96.53	94.1	91.11	86.57	81.7	73.02	62.82	51.34	39.13	28.5	18.59	8.17	2.46	0.67
	26.0	100.0	99.92	99.68	99.39	99.07	98.08	96.53	94.1	91.11	86.57	81.7	73.02	62.82	51.34	39.13	28.5	18.59	8.17	2.46	0.67
	28.0	100.0	99.92	99.68	99.39	99.07	98.08	96.53	94.1	91.11	86.57	81.7	73.02	62.82	51.34	39.13	28.5	18.59	8.17	2.46	0.67
30.0	100.0	99.92	99.68	99.39	99.07	98.08	96.53	94.1	91.11	86.57	81.7	73.02	62.82	51.34	39.13	28.5	18.59	8.17	2.46	0.67	

Second Bivariate Method

Temperature vs 100-hour Fuel Moisture

- 100-hour fuel moisture cutoff around 16%

		Temperature (°C)																			
		0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	34.0	36.0	38.0
F M 1 0 0	10.0	1.5	1.5	1.5	1.5	1.5	1.5	1.44	1.44	1.31	1.2	1.1	1.04	0.83	0.69	0.51	0.37	0.29	0.24	0.08	0.03
	12.0	15.71	15.68	15.65	15.52	15.49	15.33	14.98	14.64	13.94	12.66	11.32	9.64	7.32	5.53	3.74	2.46	1.76	1.44	0.67	0.21
	14.0	44.87	44.82	44.68	44.5	44.42	43.86	42.92	41.75	40.17	37.13	34.27	29.59	23.72	17.76	11.99	8.41	5.9	3.79	1.6	0.48
	16.0	72.97	72.89	72.65	72.41	72.17	71.26	70.03	68.32	66.11	62.34	58.28	51.23	42.52	33.41	23.77	17.01	11.51	5.9	2.14	0.64
	18.0	91.99	91.91	91.67	91.4	91.08	90.12	88.78	86.57	83.81	79.51	74.84	66.37	56.49	45.62	33.95	24.6	16.48	7.83	2.43	0.67
	20.0	98.96	98.88	98.64	98.34	98.02	97.04	95.49	93.06	90.09	85.63	80.8	72.12	61.91	50.51	38.38	27.96	18.27	8.15	2.43	0.67
	22.0	99.92	99.84	99.6	99.31	98.99	98.0	96.45	94.02	91.03	86.51	81.65	72.97	62.77	51.28	39.08	28.47	18.56	8.17	2.46	0.67
	24.0	100.0	99.92	99.68	99.39	99.07	98.08	96.53	94.1	91.11	86.57	81.7	73.02	62.82	51.34	39.13	28.5	18.59	8.17	2.46	0.67
	26.0	100.0	99.92	99.68	99.39	99.07	98.08	96.53	94.1	91.11	86.57	81.7	73.02	62.82	51.34	39.13	28.5	18.59	8.17	2.46	0.67
	28.0	100.0	99.92	99.68	99.39	99.07	98.08	96.53	94.1	91.11	86.57	81.7	73.02	62.82	51.34	39.13	28.5	18.59	8.17	2.46	0.67
	30.0	100.0	99.92	99.68	99.39	99.07	98.08	96.53	94.1	91.11	86.57	81.7	73.02	62.82	51.34	39.13	28.5	18.59	8.17	2.46	0.67

Second Bivariate Method

Temperature vs 100-hour Fuel Moisture

- Again, temperature cutoff values around 24°C (75°F)

		Temperature (°C)																			
		0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	34.0	36.0	38.0
F M 1 0 0	10.0	1.5	1.5	1.5	1.5	1.5	1.5	1.44	1.44	1.31	1.2	1.1	1.04	0.83	0.69	0.51	0.37	0.29	0.24	0.08	0.03
	12.0	15.71	15.68	15.65	15.52	15.49	15.33	14.98	14.64	13.94	12.66	11.32	9.64	7.32	5.53	3.74	2.46	1.76	1.44	0.67	0.21
	14.0	44.87	44.82	44.68	44.5	44.42	43.86	42.92	41.75	40.17	37.13	34.27	29.59	23.72	17.76	11.99	8.41	5.9	3.79	1.6	0.48
	16.0	72.97	72.89	72.65	72.41	72.17	71.26	70.03	68.32	66.11	62.34	58.28	51.23	42.52	33.41	23.77	17.01	11.51	5.9	2.14	0.64
	18.0	91.99	91.91	91.67	91.4	91.08	90.12	88.78	86.57	83.81	79.51	74.84	66.37	56.49	45.62	33.95	24.6	16.48	7.83	2.43	0.67
	20.0	98.96	98.88	98.64	98.34	98.02	97.04	95.49	93.06	90.09	85.63	80.8	72.12	61.91	50.51	38.38	27.96	18.27	8.15	2.43	0.67
	22.0	99.92	99.84	99.6	99.31	98.99	98.0	96.45	94.02	91.03	86.51	81.65	72.97	62.77	51.28	39.08	28.47	18.56	8.17	2.46	0.67
	24.0	100.0	99.92	99.68	99.39	99.07	98.08	96.53	94.1	91.11	86.57	81.7	73.02	62.82	51.34	39.13	28.5	18.59	8.17	2.46	0.67
	26.0	100.0	99.92	99.68	99.39	99.07	98.08	96.53	94.1	91.11	86.57	81.7	73.02	62.82	51.34	39.13	28.5	18.59	8.17	2.46	0.67
	28.0	100.0	99.92	99.68	99.39	99.07	98.08	96.53	94.1	91.11	86.57	81.7	73.02	62.82	51.34	39.13	28.5	18.59	8.17	2.46	0.67
	30.0	100.0	99.92	99.68	99.39	99.07	98.08	96.53	94.1	91.11	86.57	81.7	73.02	62.82	51.34	39.13	28.5	18.59	8.17	2.46	0.67