Refining the COVID-19 Model for Guilford County

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Abstract

We found the most accurate model for Covid-19 cases in Guilford County. The following weather and social variables were correlated to the number of new Covid- 19 cases: temperature, dew point, humidity, barometric pressure, wind speed, travel holidays, and weekends. Using these variables we found an amazingly accurate Covid-19 model for Guilford County.

Introduction

The coronavirus has taken the world by storm. It is a highly infectious disease that has killed over 1 million people worldwide[1]. The growth is exponential with fluctuations over time. Data has been collected from Weatherforyou.com as well as the NC database on Coronavirus cases[2]. Currently, about 3% of the population in Guilford County have been infected[2,3]. Therefore Covid-19 has potential for growth, since the super majority of the population was never infected. Knowing future case numbers, will allow hospitals to better prepare for the coming wave. Unpreparedness will undoubtedly lead to more illnesses and deaths[4].

Most COVID-19 models are exponential regressions. We started with a standard exponential regression model, E(t). $E(t) = 1.81859(t-13)^{1.6704}$

Define L(t) as the actual number of new cases at time t, after April 15. Subtract the estimate, E(t) from the number of daily cases, L(t). This provided the residual (error) based on time, we will call it R(t).

R(t)= L(t)- E(t).

Our goal is to model R(t) via polynomial regression, we will call this M(t). Please note L(t), the number of cases is given via L(t)=R(t)+E(t). Hence L(t) is estimated via M(t)+E(t). Next examine the following variables to model R(t): Average daily temperature, average daily dew point, average daily wind speed, peak daily wind gusts, average daily humidity, average daily barometric pressure, and a 0-1 function that accounts for weekends, social gatherings, and holidays. We found a polynomial regression model for the residual. Adding the original exponential model to this polynomial residual minimizes the error, therefore increases the accuracy of the model.

The following variables had the strongest correlation to the number of cases: Average daily temperature (K(t-13)), average daily relative humidity (H(t-13)), average daily wind speed(S(t-13)), peak daily wind gust speed(W(t-13)), and time (T(t-13)).

Our final model is:

$N(K(t-13), S(t-13), W(t-13), H(t-13), (t-13)) = 1.81859(t-13)^{1.6704} + 7305 - 253(K(t-13))(t-13) - 5.03(t-13) + 530(H(t-13))(t-13) - 94.6(S(t-13)) - 2.42(W(t-13)) + 2.428(K(t-13))^2 + 0.0862(t-13)^2 - 0.2878(K(t-13))(t-13) - 4.03(K(t-13))(H(t-13)) - 3.79(H(t-13))(W(t-13)) + 1.301(S(t-13))(W(t-13))$

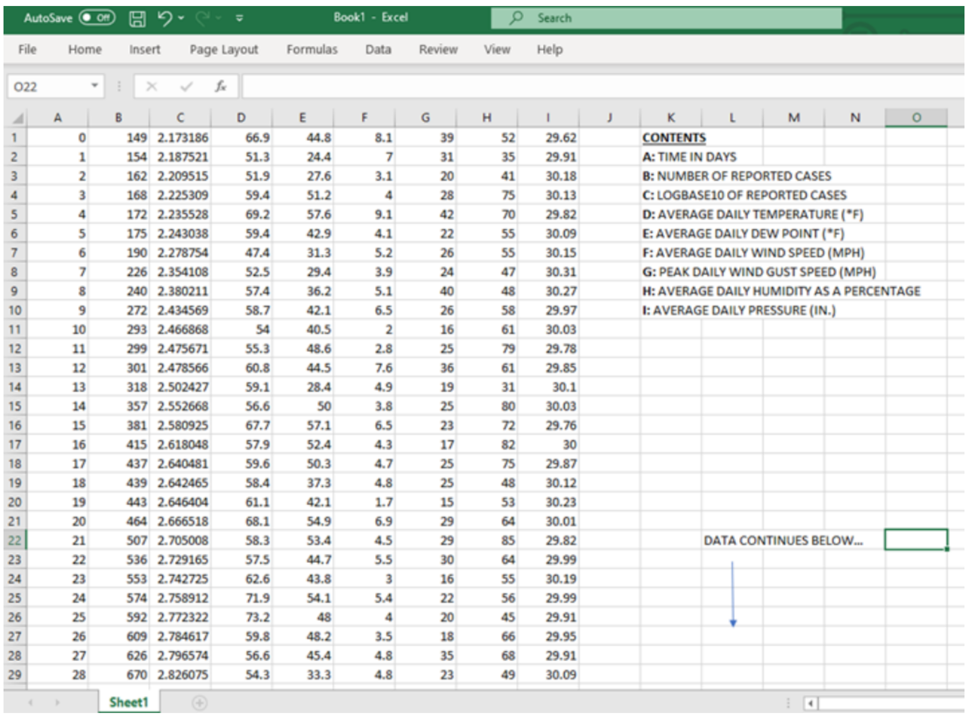
The standard error[5] of the exponential regression was 449.92; while $N(K(t-13), S(t-13), W(t-13), H(t-13), (t-13))$ had a standard error of 312.31

making it the best model for Covid-19 cases.

Methods

Data was collected on: daily averages of temperature, dew point, wind speed, wind gusts, humidity, and barometric pressure starting on March 31, 2020 from data on Weatherforyou.com. The data was compared with daily increase in COVID-19 cases in Guilford County through December 11, 2020.

Let G(t)= log(L(t)). Next we compare G(t) to the weather data with time shifts from 0 to 15 days. Let $f_i(t-i), i = 0...15$ be the regression models between G(t) and weather data from time t-i. Each $f_i(t-i)$ is associated with a R_i^2 . The i associated with the maximum R_i^2 from $\{R_i^2\}_{i=1}^{15}$ is called the lag. Here is a screenshot of the data collected. (partial list)



	A	B	C	D	E	F	G	H	I
1	0	149	2.173186	66.9	44.8	8.1	39	52	29.62
2	1	154	2.187521	51.3	24.4	7	31	35	29.91
3	2	162	2.209515	51.9	27.6	3.1	20	41	30.18
4	3	168	2.225309	59.4	51.2	4	28	75	30.13
5	4	172	2.235528	69.2	57.6	9.1	42	70	29.82
6	5	175	2.243038	59.4	42.9	4.1	22	55	30.09
7	6	190	2.278754	47.4	31.3	5.2	26	55	30.15
8	7	226	2.354108	52.5	29.4	3.9	24	47	30.31
9	8	240	2.380211	57.4	36.2	5.1	40	48	30.27
10	9	272	2.434569	58.7	42.1	6.5	26	58	29.97
11	10	293	2.466868	54	40.5	2	16	61	30.03
12	11	299	2.475671	55.3	48.6	2.8	25	79	29.78
13	12	301	2.478566	60.8	44.5	7.6	36	61	29.85
14	13	318	2.502427	59.1	28.4	4.9	19	31	30.1
15	14	357	2.552668	56.6	50	3.8	25	80	30.03
16	15	381	2.580925	67.7	57.1	6.5	23	72	29.76
17	16	415	2.618048	57.9	52.4	4.3	17	82	30
18	17	437	2.640481	59.6	50.3	4.7	25	75	29.87
19	18	439	2.642465	58.4	37.3	4.8	25	48	30.12
20	19	443	2.646404	61.1	42.1	1.7	15	53	30.23
21	20	464	2.666518	68.1	54.9	6.9	29	64	30.01
22	21	507	2.705008	58.3	53.4	4.5	29	85	29.82
23	22	536	2.729165	57.5	44.7	5.5	30	64	29.99
24	23	553	2.742725	62.6	43.8	3	16	55	30.19
25	24	574	2.758912	71.9	54.1	5.4	22	56	29.99
26	25	592	2.772322	73.2	48	4	20	45	29.91
27	26	609	2.784617	59.8	48.2	3.5	18	66	29.95
28	27	626	2.796574	56.6	45.4	4.8	35	68	29.91
29	28	670	2.826075	54.3	33.3	4.8	23	49	30.09

CONTENTS
A: TIME IN DAYS
B: NUMBER OF REPORTED CASES
C: LOGBASE10 OF REPORTED CASES
D: AVERAGE DAILY TEMPERATURE (*F)
E: AVERAGE DAILY DEW POINT (*F)
F: AVERAGE DAILY WIND SPEED (MPH)
G: PEAK DAILY WIND GUST SPEED (MPH)
H: AVERAGE DAILY HUMIDITY AS A PERCENTAGE
I: AVERAGE DAILY PRESSURE (IN.)

DATA CONTINUES BELOW...

Figure 1. The Data Collected

We performed a multiple-variable regression analysis[7]. By examining multiple time series[6], we found the lag to have the highest R^2. The lag in early November was 6 days. Medical professionals believe the average incubation period of Covid-19 is 5 days[9]. Hence, we believed there was a connection between lag, and incubation of Covid-19. However, on December 11th we reevaluated the model, the lag jumped to 13 days. The third wave has given the exponential component more impact.

Below is the report for lag testing.

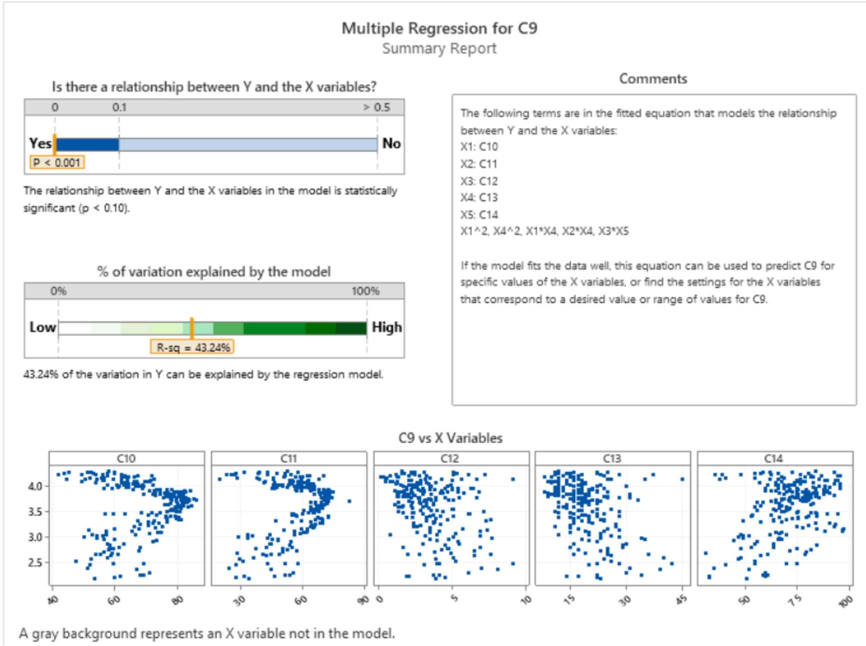


Figure 2. The results from this multivariate analysis show the highest correlation between weather and cases

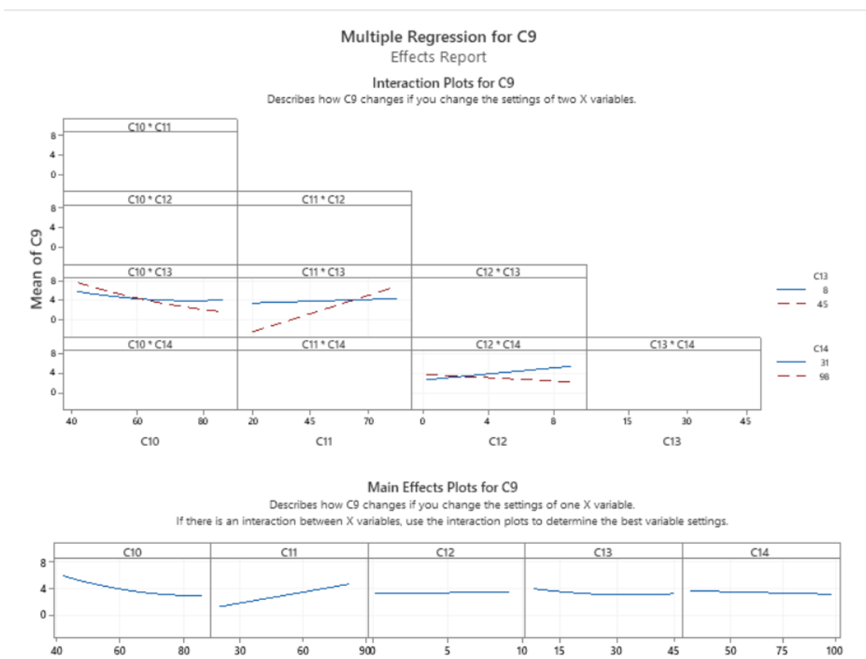


Figure 3. How each individual variable affects the residual value

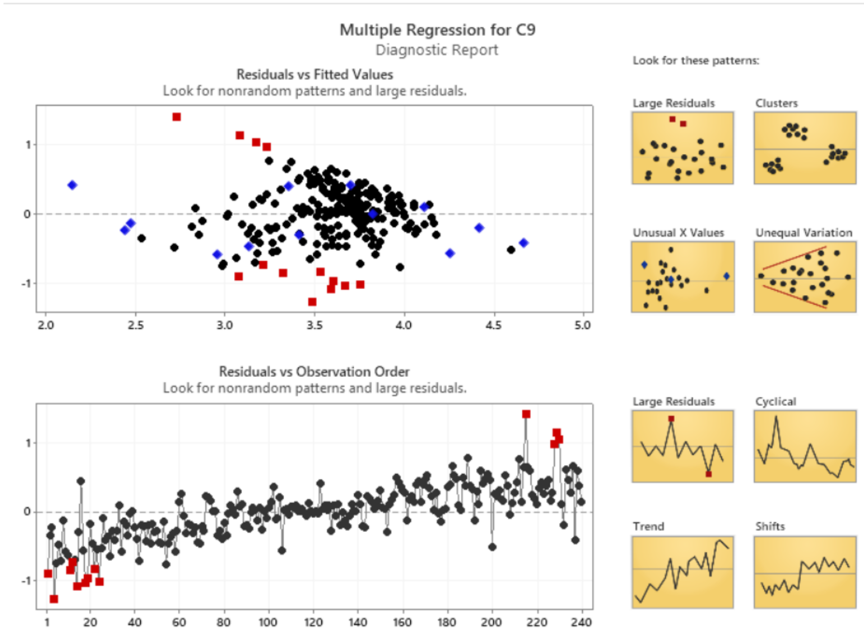


Figure 4. A random residual plot ensures that our linear correlation can be trusted

After some consideration, barometric pressure was eliminated as a variable due to its lack of predictive power. Barometric pressure can only be accurately predicted for 48 hours. The 0-1 function used to model holidays and weekends (using 1 on weekends, holidays, and social gathering periods, and 0 otherwise) was omitted due to low correlation. We used the remaining weather variables and compared them with the most accurate representation of cases for each day. First we construct an exponential model for the number of cases over time, then we add weather variables to a polynomial regression model to improve accuracy.

Using the data, with a lag of 13 days, an exponential function was calculated using nonlinear regression to fit the data. The calculated standard error was approximately 450.

$E(t) = 1.81859(t-13)^{1.6704}$; where E(t)= exponential model for number of cases at time t

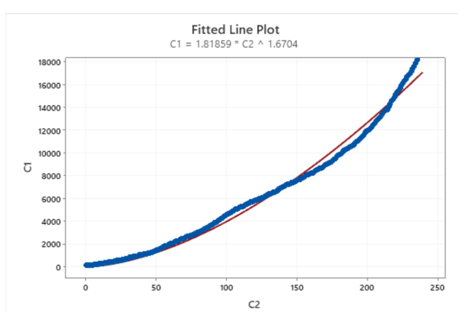


Figure 5. A nonlinear regression analysis between cases and time yields this exponential model with a standard error of roughly 450.

We found the residual value between the exponential function and the actual number of cases for each day. (Actual minus predicted). Then, we compared this daily residual value to the daily weather variables using multiple regression. After various trials of variables, the final model for the error incorporated Time in days with day 0 starting on April 2, 2020, average daily temperature (F), average daily wind speed (mph), peak daily wind gust speed (mph), and average daily relative humidity (%) for Guilford County as the explanatory variables. The standard error of the exponential model alone is approximately 450. Adding weather variables reduced the standard error to 312. Therefore, our model was a better predictor of past results.

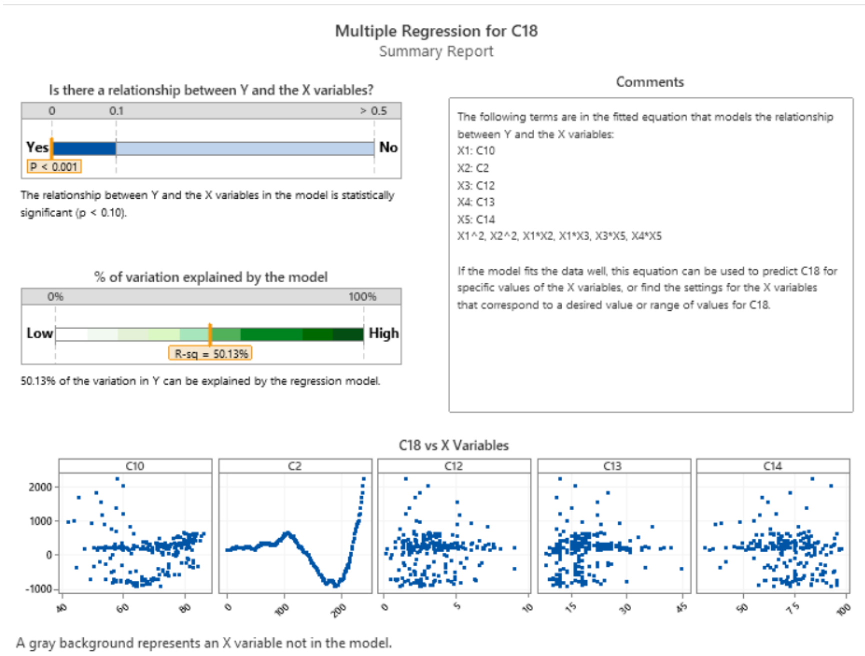


Figure 6. The results of the multivariate analysis between the residual value and weather variables

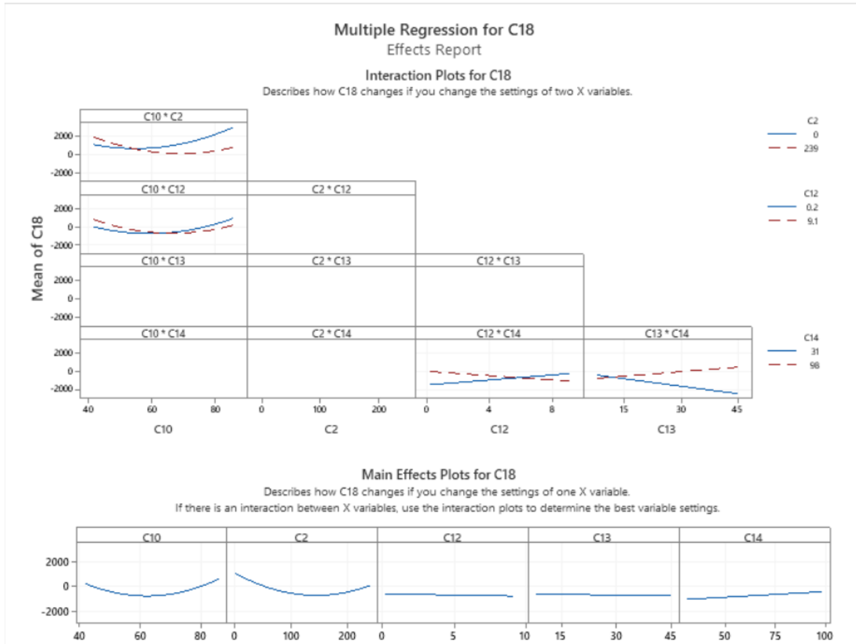


Figure 7. How each individual variable affects the residual value

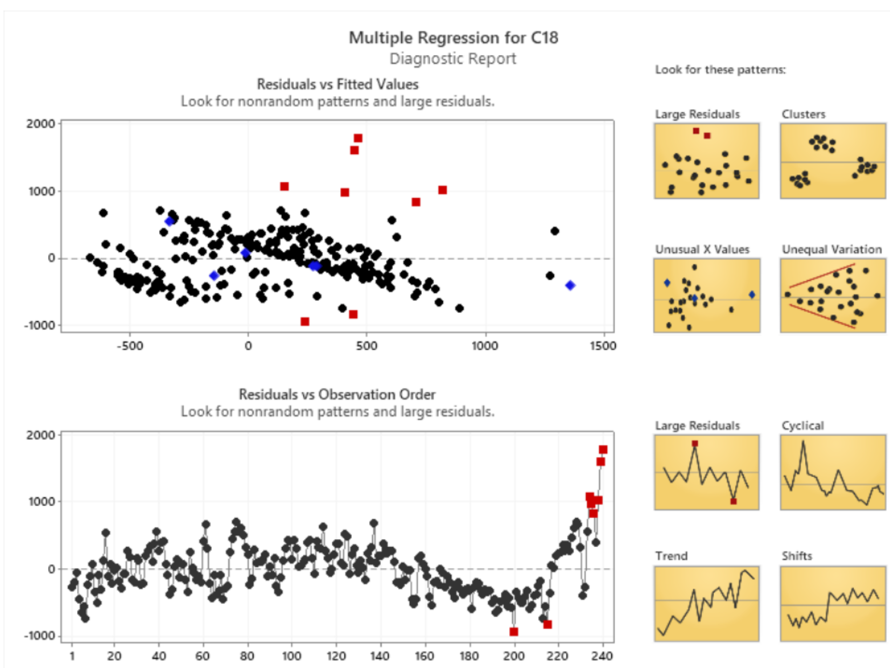


Figure 8. A random residual plot ensures that our linear correlation can be trusted

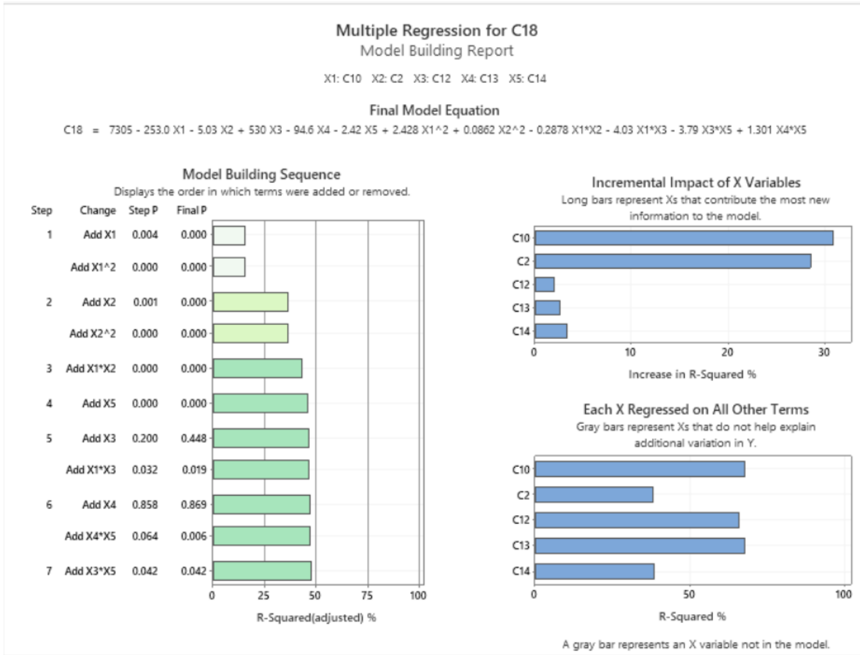


Figure 9. How the equation uses each term in the polynomial to reduce the error and improve the r-squared

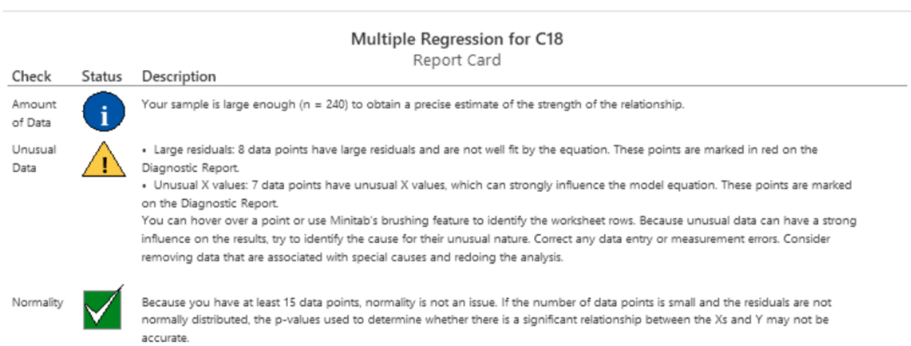


Figure 10. Our model incorporates enough data points to ensure normality

Risks

Guilford County modifies old data, categorizing new cases on the day with the onset of symptoms. Currently, we utilize data from march 31, 2020 to November 26, 2020. This implies the data used for the model will change over time, hence a new model is required after major data overhauls and updates. Therefore, we expect this model to work with minor revisions. There have also been six days in the data centers with no data. For those days, an approximation was used by taking the average number of cases for the days before and after the missing data.

Results

Let $E(t)$ be the exponential regression model for the number cases in Guilford County, where if time in days since April 15, 2020 is t, $t-13$ represents the lag that shifts the time back 13 days, to April 2, 2020.

$$E(t) = 1.81859(t-13)^{1.6704}$$

Let $K(t-13)$ represent the average daily temperature for a given lagged day.

Let $S(t-13)$ represent the average daily wind speed for a given lagged day.

Let $W(t-13)$ represent the average daily wind gust speed for a given lagged day.

Let $H(t-13)$ represent the average daily humidity for a given lagged day.

Let $M(K(t-13), S(t-13), W(t-13), H(t-13), (t-13))$ with Average daily temperature $K(t-13)$, average daily wind speed $S(t-13)$, peak daily wind gust speed $W(t-13)$, average daily humidity $H(t-13)$ and lagged time $(t-13)$ be the multiple regression function that estimates the daily residual between the exponential function and the actual amount of cases:

$$M(K(t-13), S(t-13), W(t-13), H(t-13), (t-13)) = \\ 7305 - 253(K(t-13))(t-13) - 5.03(t-13) + 530(H(t-13))(t-13) - 94.6(S(t-13)) - \\ 2.42(W(t-13)) + 2.428(K(t-13))^2 + 0.0862(t-13)^2 - 0.2878(K(t-13))(t-13) - \\ 4.03(K(t-13))(H(t-13)) - 3.79(H(t-13))(W(t-13)) + 1.301(S(t-13))(W(t-13)).$$

Adding $E((t-13)$ and $M(K(t-13), S(t-13), W(t-13), H(t-13), (t-13))$ creates a function $N(K(t-13), S(t-13), W(t-13), H(t-13), (t-13))$, with the same parameters as above, which improves upon the initial exponential function by stripping the projected error, hence improving the model.

$$N(K(t-13), S(t-13), W(t-13), H(t-13), (t-13)) = \\ E(t-13) + M(K(t-13), S(t-13), W(t-13), H(t-13), (t-13))$$

$$N(K(t-13), S(t-13), W(t-13), H(t-13), (t-13)) = \\ 1.81859(t-13)^{1.6704} + 7305 - 253(K(t-13))(t-13) - 5.03(t-13) + 530(H(t-13))(t-13) - \\ 94.6(S(t-13)) - 2.42(W(t-13)) + 2.428(K(t-13))^2 + 0.0862(t-13)^2 - 0.2878(K(t-13))(t- \\ 13) - 4.03(K(t-13))(H(t-13)) - 3.79(H(t-13))(W(t-13)) + 1.301(S(t-13))(W(t-13))$$

The standard error for N is about 312, a substantial improvement from the initial 450. Therefore, $N(K(t-13), S(t-13), W(t-13), H(t-13), (t-13))$ is a more accurate predictor for future case growth in Guilford county.

Conclusion

Our goal is to assist Guilford county prepare for the Coronavirus. The first step is to accurately predict the number of cases. The model $N(K(t-13), S(t-13), W(t-13), H(t-13), (t-13))$ is the best predictor of cases in the county. This will allow medical professionals to secure necessary hospital beds as the pandemic grows. Shortages of health care beds and equipment was catastrophic in NYC at the onset of the virus[4].

Using our improved model, we can make better predictions concerning the future growth of Coronavirus in the future weeks to come, assuming that no drastic event occurs that could substantially alter the number of future cases.Note that the validity of these predictions also depends on the accuracy of future forecasts.

Three weeks from December 11, 2020, we expect the total number of cases within Guilford County to be roughly 22748 cases. In the next four weeks from December 11, 2020, that number will rise to approximately 25246 cases.

References

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