Evidence that higher temperatures are associated with lower incidence of COVID-19 in pandemic state, cumulative cases reported up to March 27, 2020

Michael Triplett[1,2]

Affiliations

1 TerumoBCT, 10811 Collins Ave, Lakewood, CO 80215
2 University of Colorado Denver, 1201 Larimer St, Denver, CO 80204

Corresponding Author Information
Michael Triplett
Email: michael.triplett@terumobct.com; michael.triplett@ucdenver.edu

Abstract
Seasonal temperature variation may impact the trajectories of COVID-19 in different global regions. Cumulative data reported by the World Health Organization, for dates up to March 27, 2020[1], show association between COVID-19 incidence and regions at or above 30° latitude. Historic climate data also show significant reduction of case rates with mean maximum temperature above approximately 22.5 degrees Celsius. Variance at the local level, however, could not be well explained by geography and temperature. These preliminary findings support continued countermeasures and study of SARS-CoV-2/COVID-19 transmission rates by temperature and humidity.

Keywords
COVID-19; SARS-CoV-2; confirmed cases; case rates; latitude; temperature; pandemic; coronavirus

Conflicts of Interest
None

Funding Statement
No funding was awarded for this research

Background

In recent months, pandemic COVID-19, which is caused by a coronavirus called SARS-CoV-2 that originated in Wuhan, China, has spread rapidly across temperate regions of the northern hemisphere[6]. Concurrent speculation has grown about the trajectory of the virus in various regions. On March 30, 2020 Dr. Marc Lipsitch, Professor of Epidemiology at Harvard University, said, "It's really clear that warmer weather does not stop the transmission or growth of the virus… There's no question that coronaviruses are capable of transmitting in hotter, humid climates."[10] However, several early studies, yet to be peer reviewed at the time of this research, indicate reduced transmission with increased temperature[4,6,7]. Some respiratory conditions, like influenza, are already known to show consistent seasonality. Study of SARS coronavirus, which broke out in Hong Kong in 2003, has also shown dependence on temperature and humidity[5,8]. This study aims to provide data supporting further research of the effects of temperature and humidity on COVID-19/SARS-CoV-2.

Materials and Methods

Daily COVID-19 situation reports provided by the World Health Organization (WHO) were obtained for dates beginning March 14 and ending March 27[1]. Information included cumulative case data for all reporting nations. Confirmed case counts were recorded for all nations for the dates listed. Population data assigned to reporting nations were taken from UN estimates of "Total population, both sexes combined" (UNdata, United Nations Statistics Division, 17 June 2019) and used to calculate confirmed case rates (confirmed cases / population). Nations showing case rates above 0.1% with populations less than 1 million were treated as outliers and omitted from analysis. Nations without available predictor data (i.e. population) were also omitted from analysis.

Population values were assigned locations for case-mapping by taking the average (middle) of each nation's most extreme latitudes and longitudes (i.e. the latitudes and longitudes of each nation's northern-, eastern-, southern- and western-most points). For nations in the western hemisphere above 40 degrees latitude at center, and for nations in the eastern hemisphere above 60 degrees latitude at center, populations were assumed to be concentrated near the southernmost border. Fig. 1 shows how populations were represented from -65° to 65° degrees latitude

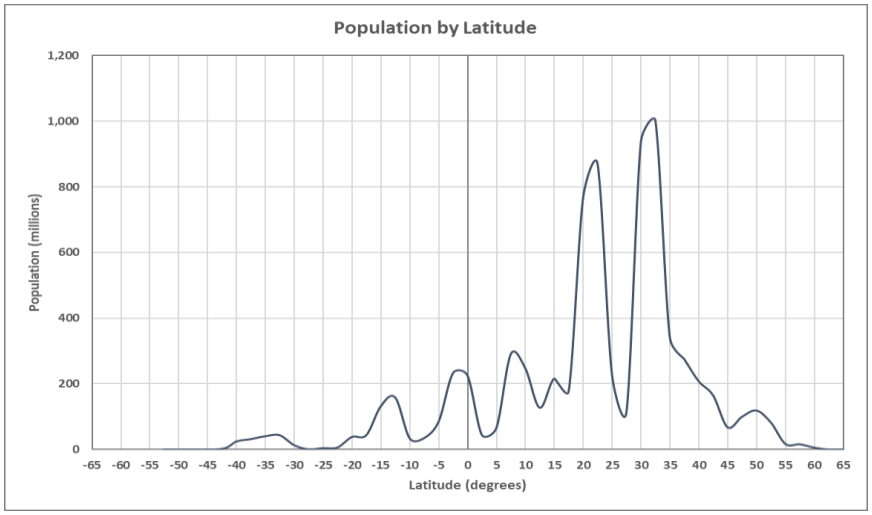

Figure 1: Global population as modeled by assigned latitude

Global gridded daily maximum surface temperature data, with 0.5° spatial resolution, for the dates from February 29 to March 14, 2020, were accessed from the US National Oceanic and Atmospheric Administration (NOAA), Earth system research Laboratory (ESRL), Physical Sciences Division website (ftp://ftp.cdc.noaa.gov/Datasets/cpc_global_temp/)[3]. Dates two weeks prior to respective case dates were chosen to account for 14 days between transmission and case confirmation. As shown in fig. 2, recorded mean maximum temperature values were averaged across each reported latitude for each day and assigned to reporting nations based on modeled population latitudes.

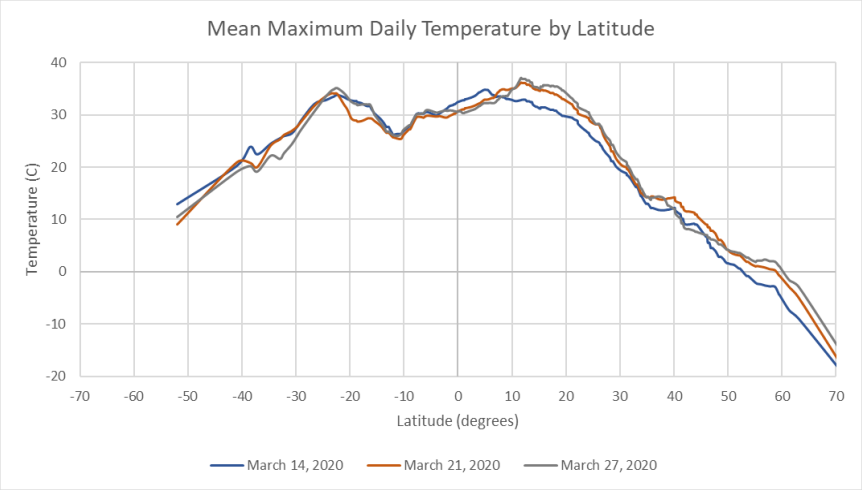

Figure 2: Mean maximum surface temperature by latitude for March 14, March 21 and March 27, 2020

For data reported March 27, 2020, multiple linear regression analysis[12] was then performed for confirmed cases at the national level using estimated populations and mean maximum temperatures at assigned latitudes as predictors. Case data was transformed using the Box-Cox[14] method with $\lambda = 0$. To reduce variance, populations were then binned[11] into 5º latitude and temperature ranges set at 2.5º intervals. Multiple linear regression was then performed for confirmed cases binned by latitude, again using population and mean maximum temperature as predictors, with and without a categorical variable describing bins above and below 30º latitude. Confirmed case data binned by latitude was transformed, again using the Box-Cox method, with $\lambda = 0.212028$ for analysis including the categorical variable and $\lambda = 0$ for analysis without. Nonlinear regression analysis[13] was also performed, without transformation, for case rates binned by mean maximum temperature at latitude, using temperature as the only predictor.

No other adjustments were made to original data. Inclusion of multiple dates and binning of data is intended to reduce low-level (i.e. national level) variance associated with local weather, travel restrictions, business closures and other countermeasures. No speculation is made outside the scope of the data.

Results and Discussion

***Confirmed cases* and *case rates* plotted by *latitude* (fig. 3)** showed a separation of cases in nations with central or southern latitudes north of 30º. As of March 27, case rates also appeared to be increasing south of -30º latitude, where temperatures fall first with transition to the fall season. That increase provided initial indication that the correlation with latitude is likely due to the underlying relationship with temperature.

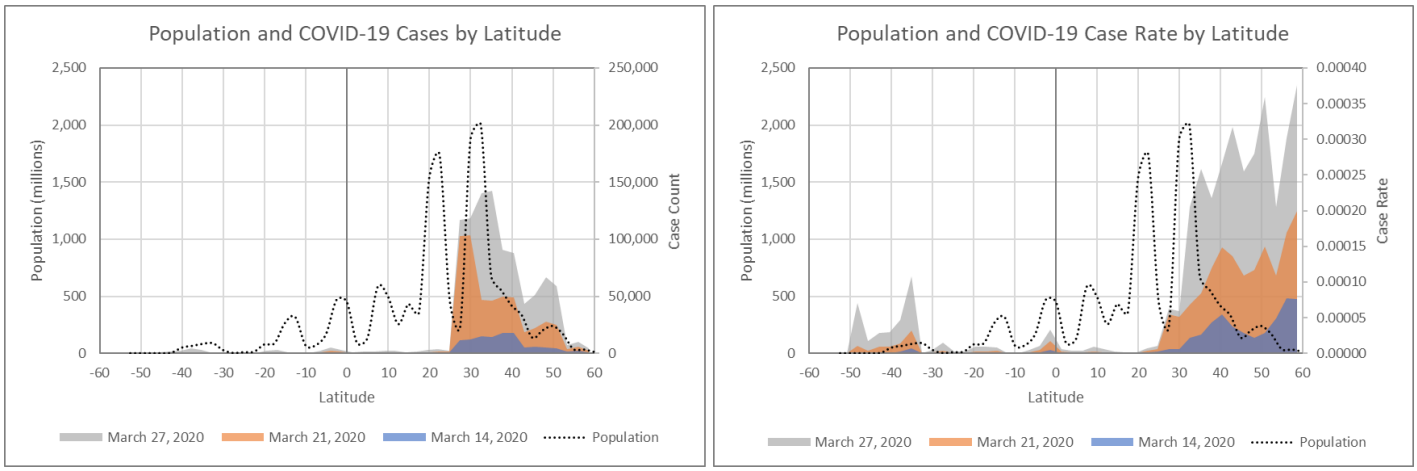

Figure 3: Confirmed cases and case rates by latitude for March 14, 21 and 27, 2020. The separation between cases above and below 30º latitude is clearly visible. Case rates also appear to increase below -30º latitude, where temperatures are lowest in the southern hemisphere.

Binned *confirmed cases* and *case rates* plotted by *temperature* (fig. 4) showed increased growth patterns in ranges below 22.5ºC, and a downward trend could be seen in case rates as temperatures increase to the same point. Above 22.5ºC, case rates remained near-zero. It should also be noted that high-growth regions appeared to be warming between March 14 and 27, but case rates remained near-zero in regions above 22.5ºC during that time. Slight growth was observed above that temperature, but rates are significantly slower.

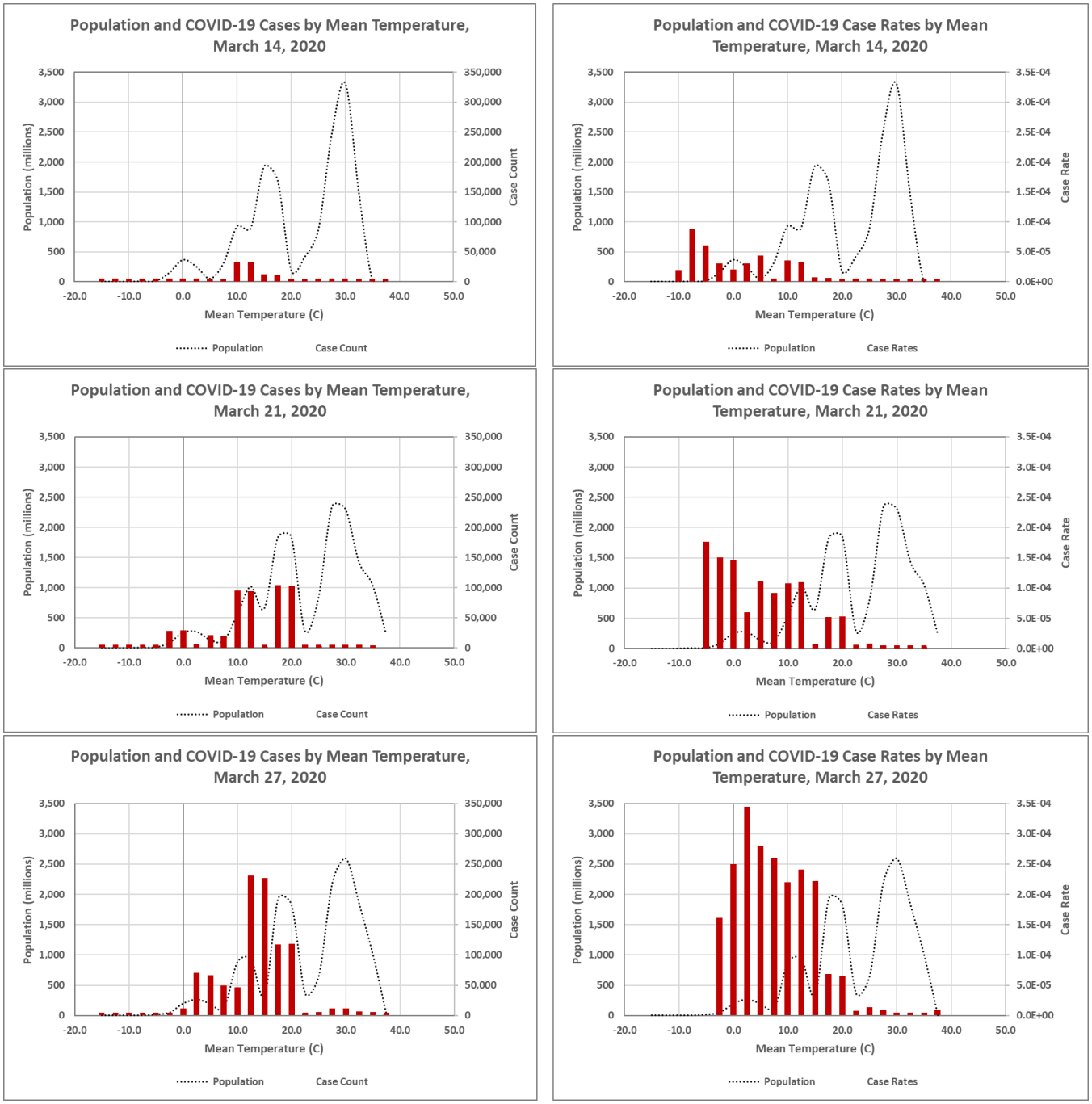

Figure 4: Confirmed cases and case rates by mean maximum temperature for March 14, March 21 and March 27, 2020. The trend of decreasing case rates with increased temperature, until approximately 22.5ºC, above which case rates remain near-zero.

Multiple linear regression of *confirmed cases* by *population* and *temperature*, for data reported March 27, 2020, showed a significant relationship between population and mean maximum temperature at the assigned latitude, with reported p-values <0.000 for both predictors and the constant. Residual values and distribution also indicated a good fit for the model. However, R^2 of 26.52% showed that the model could only explain a small portion of low-level variance.

Model Summary for Transformed Response		
R^2(transformed)	37.34%	
R^2(normal)	26.52%	
Coefficients for Transformed Response		
Term	**Coefficent**	**P-Value**
Constant	39.16877118	1.78662E-19
Population	5.07058E-09	1.61722E-06
Temperature (ºC)	-0.118552724442517	2.12551E-16
Regression Equation		
ln(Confirmed Cases) = 39.16877118 + 5.07058E-09 Population - -0.118552724442517 Temperature Confirmed Cases = exp(39.16877118 + 5.07058E-09 Population - -0.118552724442517 Temperature)		

Table 1: Summary of multiple linear regression of confirmed cases by population and temperature. P-values indicate statistical significance of predictors, but R^2 indicates that the model explains only a small portion of low-level variance.

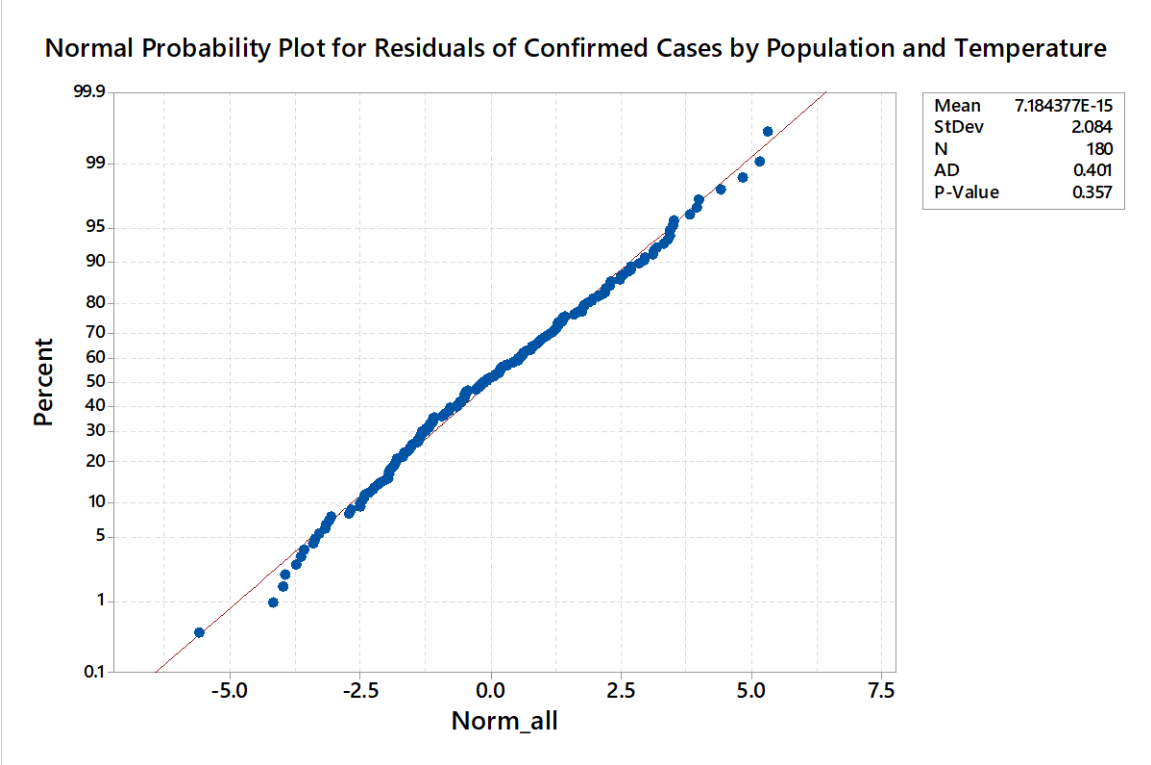

Figure 5: Normal probability plot for residuals of confirmed cases at the national level, as predicted by population and temperature. The normal distribution of residuals and mean near zero indicate a good fit for the model.

Multiple linear regression of binned *confirmed cases* by *population*, *temperature* and *latitude (above/below 30º)* also showed a significant relationship between response and continuous predictors. Transformed R^2 improved to 84.61%, but the categorical variable for cases above and below 30º latitude could only be claimed with 84.7% confidence. Removing that variable showed similar significance for temperature and population predictors but reduced transformed R^2 to 65.27%. R^2 only improved to 30.92%, which is still an insignificant amount of variance explained. Normal probability plots of residuals also indicate a poor fit for the model – normality should be rejected with a p-value of 0.028.

Model Summary for Transformed Response		
R^2(transformed)	65.27%	
R^2(normal)	30.92%	
Coefficients for Transformed Response		
Term	**Coefficent**	**P-Value**
Constant	10.58762191	1.68022E-21
Population	-0.136589856	1.71103E-08
Temperature (ºC)	1.77677E-09	0.000379889
Regression Equation		
ln(Confirmed Cases) = 10.58762191 - 0.136589856 Population + 1.77677E-09 Temperature Confirmed Cases = exp(10.58762191 - 0.136589856 Population + 1.77677E-09 Temperature)		

Table 2: Summary of multiple linear regression results. P-values indicate statistical significance of predictors, but R^2 indicates that the model explains only a small portion of binned variance.

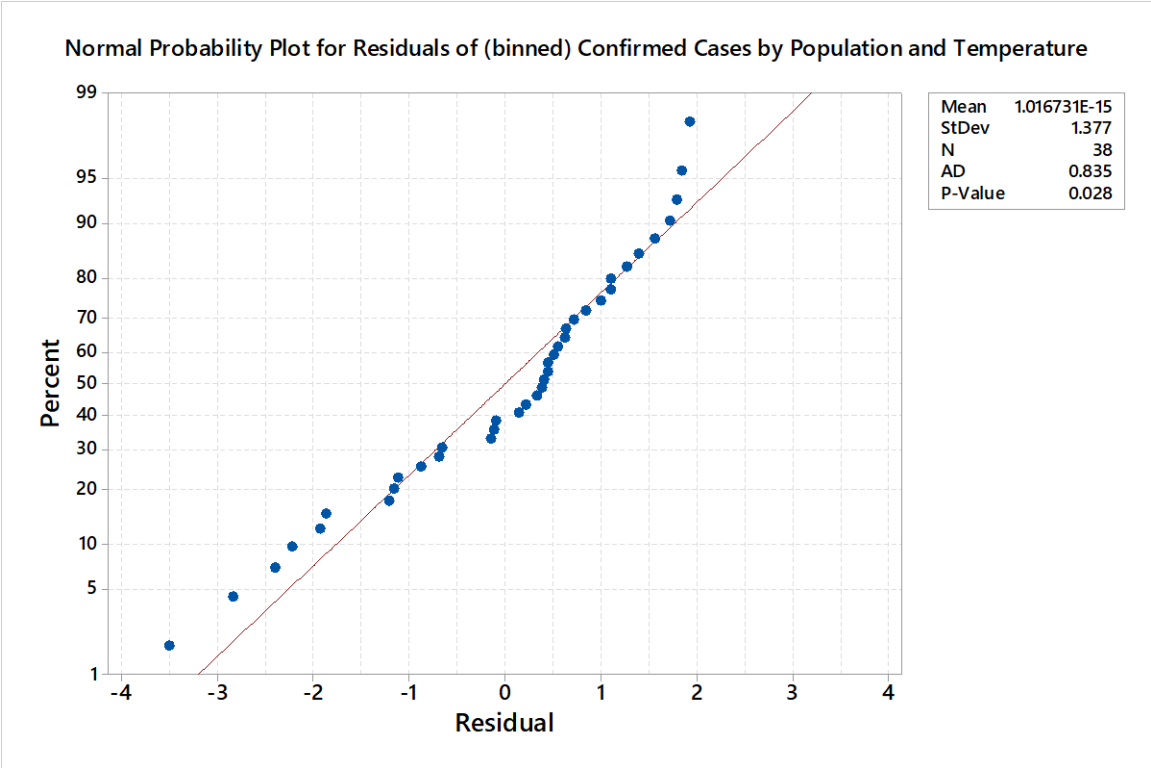

Figure 6: Normal probability plot for residuals of (binned) confirmed cases by population and temperature. The distribution of residuals indicates that the model is not a good fit for the mode.

Nonlinear regression of *case rates* by *temperature* returned the best fit of all presented models. P-values cannot be calculated for independent nonlinear regression variables, so significance could not be determined with that method. However, R^2 of 93.78% and normality test of residuals with p-value = 0.546 indicated a good fit for the model until case rates converge near zero above 22.5ºC. Fig. 7 shows the close fit between predicted and actual values in that range.

Nonlinear Regression Summary
Case Rate by Temperature = (0.0002166 - 7.03186e-006 Temperature) / (1 - 0.0930346 Temperature + 0.00495066 * Temperature^2)
R^2 = 93.78%

Table 3: Summary of nonlinear regression results. R^2 of 93.78% shows that the model can explain the majority of binned variance.

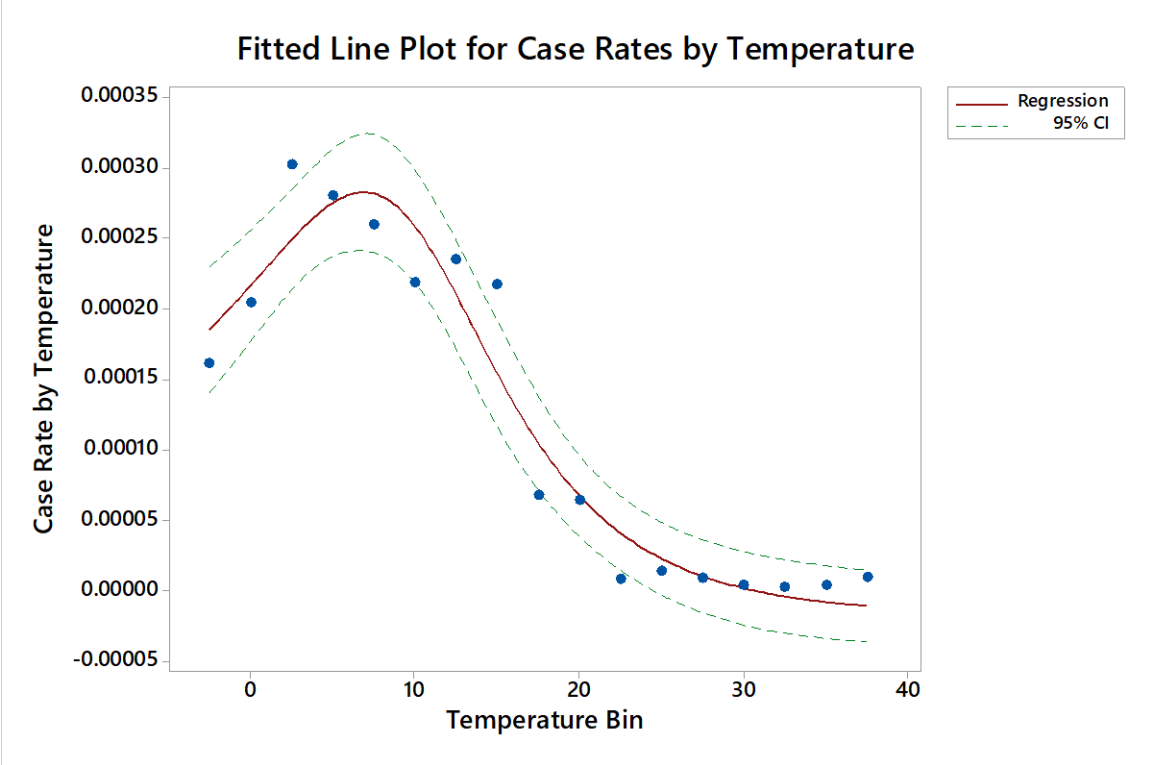

Figure 7: Fitted line plot for nonlinear regression of *case rates* by *temperature*. A close fit between predicted and actual values is apparent until the model begins to diverge from data (i.e. move below zero) above 22.5ºC. Case rates remain near-zero above that temperature.

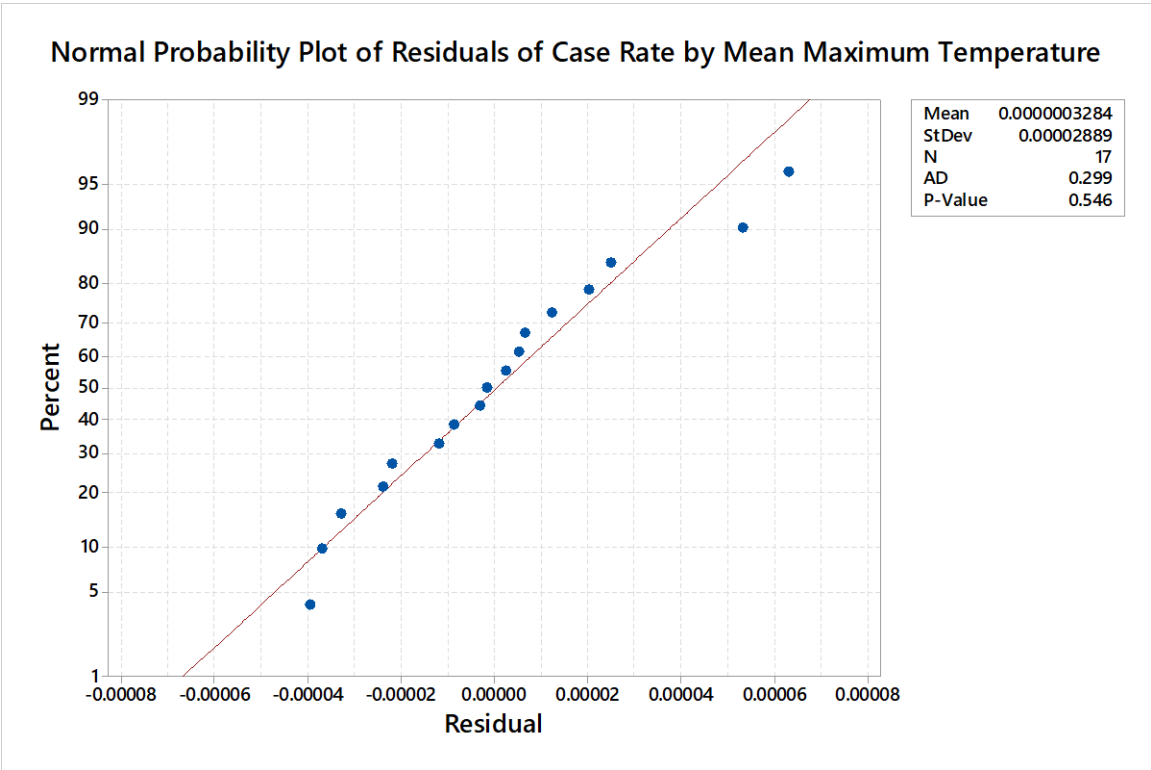

Figure X: Normal probability of residuals for *case rates* by *mean maximum temperature*. The normal distribution of residuals with mean near-zero indicate a good fit for the model.

Nonlinear regression results for case data reported March 27, 2020 indicated a strong regional-level correlation between COVID-19 case rates and mean maximum surface air temperatures below 22.5ºC. Case rates peaked in a goldilocks range around 7.5ºC and were uniformly distributed near zero at temperatures above 22.5ºC. That breakpoint was shown to be a

consistent maximum across the dates included in analysis – i.e. case rates have been observed near zero below that temperature but have not been observed to increase significantly above it.

In conflict with the model for March 27, case rates reported for March 14 and 21 trended continuously upward with decreased temperature below 22.5ºC. Nonlinearity for the most recent data might be explained by typical warming trends in northern latitudes that move case rate and population distributions to the right through March; variance in national- and local-level countermeasures may have effected growth in northern regions; the virus naturally peaks at lower levels in extremely cold and sparsely populated northern temperate/polar regions; and/or the virus simply had not yet taken hold in its goldilocks zone during previous periods. Regardless of cold weather dynamics, however, the breakpoint of 22.5ºC remains apparent.

These conclusions do not confirm that COVID-19 cannot survive or transmit in warm and humid temperatures or establish a casual connection between temperature and transmission. However, the clear correlation between variables provides support for further study of SARS-CoV-2 and COVID-19 under various environmental conditions. With respect to countermeasures, the southern hemisphere should also expect increased case rates as that region moves from summer into fall and winter.

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Appendix: Reported Data

National Data			Average Temperature at Latitude			Confirmed Cases Reported		
Area	Study Latitude	Population	14-Mar	21-Mar	27-Mar	14-Mar	21-Mar	27-Mar
Afghanistan	33.93	38,928,341	13.46	14.99	15.95	7	24	80
Albania	41.15	2,877,800	8.77	13.09	10.26	33	70	186
Algeria	28.13	43,851,043	22.06	23.94	25.14	26	94	305
Angola	-11.21	32,866,268	26.37	25.41	25.96	0	0	2
Antigua and Barbuda	17.34	97,928	31.80	34.10	35.55	1	1	3
Argentina	-38.48	45,195,777	23.48	20.78	20.23	34	128	502
Armenia	40.07	2,963,234	10.02	14.16	12.01	8	136	329
Aruba	12.49	106,766	34.59	36.02	36.85	0	5	19
Australia	-32.21	25,499,881	27.28	26.10	22.68	197	873	2985
Austria	47.70	9,006,400	2.17	7.23	6.00	504	2649	7029
Azerbaijan	40.17	10,139,175	10.02	14.16	12.01	11	44	122
Bahamas	24.09	393,248	27.14	29.36	30.52	0	4	5
Bahrain	26.11	1,701,583	25.59	28.04	28.31	210	285	458
Bangladesh	23.51	164,689,383	27.44	29.65	30.84	3	17	48
Barbados	13.19	287,371	34.16	35.70	36.57	0	5	18
Belarus	53.71	9,449,321	-0.38	1.85	2.78	21	57	86
Belgium	50.52	11,589,616	0.74	3.61	3.97	599	2257	6235
Belize	17.19	397,621	31.83	34.10	35.42	0	0	2
Benin	9.22	12,123,198	34.70	34.68	33.62	0	2	6
Bermuda	32.32	62,273	15.85	17.74	18.62	0	2	7
Bhutan	27.47	771,612	22.96	24.97	25.85	1	2	3
Bolivia (Plurinational State of)	-16.28	11,673,029	29.31	29.28	31.99	3	16	39
Bosnia and Herzegovina	43.92	3,280,815	5.37	10.89	7.69	11	44	213
Brazil	-14.29	212,559,409	29.02	27.85	28.43	98	621	2433
Brunei Darussalam	4.55	437,483	35.16	32.56	32.09	25	78	114
Bulgaria	42.73	6,948,445	6.13	11.47	8.20	7	127	264
Burkina Faso	12.25	20,903,278	34.77	36.02	36.86	2	40	146
Cabo Verde	16.00	555,988	32.24	34.59	35.67	0	1	3
Cambodia	12.08	16,718,971	34.77	36.02	36.86	7	51	98
Cameroon	7.37	26,545,864	34.85	34.23	32.89	2	22	75
Canada	41.68	37,742,157	7.93	12.34	9.30	176	846	3555
Cayman Islands	19.51	65,720	30.61	32.97	34.66	1	3	8
Central African Republic	6.61	4,829,764	34.70	33.17	32.23	0	1	5
Chad	15.47	16,425,859	32.07	34.70	35.41	0	1	5

Chile	-37.11	19,116,209	22.63	19.99	19.19	43	434	1306
China	31.20	1,439,323,774	18.00	19.89	21.01	0	81416	82078
Colombia	5.91	50,882,884	35.13	32.99	32.30	16	145	470
Congo	-0.72	5,518,092	31.36	30.16	30.70	0	3	4
Costa Rica	8.28	5,094,114	34.91	34.83	33.57	23	113	201
Côte d'Ivoire	7.45	26,378,275	34.85	34.23	32.89	0	9	80
Croatia	44.37	4,105,268	4.94	10.52	7.59	27	126	495
Cuba	21.55	11,326,616	28.73	31.18	32.60	4	16	67
Curaçao	12.17	164,100	34.77	36.02	36.86	0	3	7
Cyprus	35.18	1,207,361	12.20	14.22	14.36	14	67	146
Czechia	49.80	10,708,982	0.86	4.15	4.27	150	904	2062
Democratic Republic of the Congo	-4.03	89,561,404	30.00	29.62	30.45	2	14	54
Denmark	56.20	5,792,203	-2.40	0.89	2.16	801	1255	1877
Djibouti	11.85	988,002	34.77	36.02	36.86	0	1	12
Dominica	15.40	71,991	32.07	34.70	35.41	0	0	11
Dominican Republic	19.29	10,847,904	30.61	32.97	34.66	5	72	488
Ecuador	-1.57	17,643,060	30.73	29.73	30.84	23	367	1211
Egypt	26.92	102,334,403	23.98	26.07	26.82	93	256	495
El Salvador	13.71	6,486,201	33.63	35.43	36.17	0	1	13
Equatorial Guinea	1.16	1,402,985	32.37	30.98	30.35	0	4	6
Eritrea	15.21	3,546,427	31.90	34.52	35.03	0	0	6
Estonia	58.72	1,326,539	-3.85	0.22	1.97	79	283	538
Eswatini	26.52	1,160,164	24.97	27.33	27.81	0	1	6
Ethiopia	9.15	114,963,583	34.70	34.68	33.62	1	9	12
Fiji	-17.10	896,444	29.47	29.07	32.04	0	1	5
Finland	59.45	5,540,718	-5.04	-0.76	1.11	109	450	958
France	46.27	65,273,512	2.94	8.46	6.59	3640	12475	28786
French Guiana	3.93	298,682	34.72	32.13	31.68	6	15	28
French Polynesia	-17.88	280,904	29.64	28.74	31.97	1	11	30
Gabon	-0.89	2,225,728	31.09	30.05	30.80	1	3	6
Gambia	13.44	2,416,664	33.63	35.43	36.17	0	1	2
Georgia	42.32	3,989,175	6.13	11.47	8.20	25	43	81
Germany	51.18	83,783,945	0.69	3.28	3.85	3062	18323	42288
Ghana	7.86	31,072,945	34.96	34.68	33.39	1	16	132
Greece	38.22	10,423,056	10.87	13.75	13.98	98	495	892
Greenland	59.52	56,772	-5.04	-0.76	1.11	0	2	6
Grenada	12.19	112,519	34.77	36.02	36.86	0	0	7
Guadeloupe	16.17	400,127	32.24	34.59	35.67	1	51	76
Guam	13.44	168,783	33.63	35.43	36.17	0	14	45
Guatemala	15.73	17,915,567	32.07	34.70	35.41	0	12	24
Guinea	9.93	13,132,792	34.48	34.96	34.75	1	2	5
Guyana	4.89	786,559	35.25	32.83	32.25	1	5	5
Haiti	19.06	11,402,533	30.85	33.30	35.01	0	2	8
Honduras	15.30	9,904,608	32.07	34.70	35.41	2	24	52
Hungary	47.16	9,660,350	2.45	7.78	6.21	19	85	300
India	21.11	1,380,004,385	29.26	31.99	33.21	82	195	724
Indonesia	-2.47	273,523,621	30.42	29.45	30.81	69	369	893
Iran (Islamic Republic of)	32.31	83,992,953	15.85	17.74	18.62	11364	19644	29406

Iraq	33.22	40,222,503	14.88	16.63	17.69	93	193	382
Ireland	53.43	4,937,796	-0.38	1.85	2.78	90	683	1819
Isle of Man	54.24	85,032	-0.82	1.43	2.36	0	1	26
Israel	31.39	8,655,541	17.51	19.56	20.41	100	712	3035
Italy	41.19	60,461,828	8.77	13.09	10.26	17660	47021	80539
Jamaica	17.66	2,961,161	31.80	34.10	35.55	7	16	26
Japan	32.96	126,476,458	14.88	16.63	17.69	716	996	1387
Jordan	31.28	10,203,140	17.51	19.56	20.41	1	69	212
Kazakhstan	48.01	18,776,707	1.82	6.53	5.68	0	53	125
Kenya	-0.14	53,771,300	31.76	30.53	30.59	1	7	25
Kuwait	29.31	4,270,563	19.55	21.51	22.82	100	159	208
Kyrgyzstan	41.22	6,524,191	8.77	13.09	10.26	0	6	58
Lao People's Democratic Republic	18.21	7,275,556	31.49	33.83	35.40	0	0	6
Latvia	56.88	1,886,202	-2.92	0.74	2.38	16	111	244
Lebanon	33.87	6,825,442	13.46	14.99	15.95	77	163	368
Liberia	6.35	5,057,677	34.70	33.17	32.23	0	2	3
Libya	26.43	6,871,287	24.97	27.33	27.81	0	0	1
Lithuania	55.17	2,722,291	-1.47	0.96	1.91	6	69	299
Madagascar	-18.78	27,691,019	29.90	28.86	32.13	0	0	24
Malaysia	2.39	32,365,998	33.39	31.43	30.83	197	1030	2031
Maldives	3.20	540,542	33.99	31.75	31.13	9	13	13
Malta	35.94	441,539	12.01	14.34	14.17	12	64	134
Martinique	14.64	375,265	32.36	34.74	35.30	6	32	66
Mauritania	21.02	4,649,660	29.26	31.99	33.21	0	2	3
Mauritius	-15.43	1,271,767	28.68	28.76	29.99	0	12	81
Mayotte	-12.83	272,813	28.23	26.51	26.80	0	4	50
Mexico	23.55	128,932,753	27.44	29.65	30.84	26	164	478
Monaco	43.74	39,244	5.78	11.25	7.88	2	12	19
Mongolia	46.86	3,278,292	2.45	7.78	6.21	1	6	11
Montenegro	42.65	628,062	6.13	11.47	8.20	0	14	67
Montserrat	16.75	4,999	31.98	34.36	35.64	0	1	2
Morocco	28.69	36,910,558	20.92	22.95	24.27	7	74	275
Mozambique	-18.62	31,255,435	29.82	28.66	31.87	0	0	5
Myanmar	18.99	54,409,794	30.85	33.30	35.01	0	0	5
Namibia	-22.97	2,540,916	32.90	34.02	34.88	0	3	8
Nepal	28.40	29,136,808	20.92	22.95	24.27	1	1	3
Netherlands	52.23	17,134,873	0.60	3.08	3.63	804	2994	7431
New Caledonia	-20.45	285,491	30.87	30.92	33.39	0	2	14
New Zealand	-40.93	4,822,233	22.45	20.87	19.14	6	53	338
Nicaragua	12.87	6,624,554	34.16	35.70	36.57	0	1	2
Niger	17.61	24,206,636	31.80	34.10	35.55	0	1	10
Nigeria	8.98	206,139,587	34.70	34.68	33.62	2	12	65
North Macedonia	41.61	2,083,380	7.93	12.34	9.30	9	70	201
Norway	57.76	5,421,242	-3.65	0.43	2.06	750	1742	3156
Oman	21.58	5,106,622	28.73	31.18	32.60	19	48	109
Pakistan	30.31	220,892,331	18.59	20.31	21.58	21	461	1057
Panama	8.45	4,314,768	34.91	34.83	33.57	27	137	558
Papua New Guinea	-5.68	8,947,027	30.10	29.79	30.95	0	1	1

Paraguay	-23.45	7,132,530	33.09	34.04	34.60	6	13	41
Peru	-10.12	32,971,846	27.29	26.02	27.09	28	234	580
Philippines	12.77	109,581,085	34.16	35.70	36.57	64	230	707
Poland	52.02	37,846,605	0.60	3.08	3.63	64	425	1221
Portugal	35.99	10,196,707	12.01	14.34	14.17	112	1020	3544
Puerto Rico	18.22	2,860,840	31.49	33.83	35.40	3	14	64
Qatar	25.43	2,881,060	25.79	28.14	28.35	262	460	549
Republic of Korea	35.77	51,269,183	12.01	14.34	14.17	8086	8799	9332
Republic of Moldova	46.98	4,033,963	2.45	7.78	6.21	8	66	177
Réunion	-21.13	895,308	31.55	31.98	34.19	5	28	135
Romania	45.94	19,237,682	3.49	8.97	7.06	64	308	1029
Russian Federation	41.19	145,934,460	8.77	13.09	10.26	34	253	1036
Rwanda	-1.94	12,952,209	30.42	29.47	30.77	0	11	50
Saint Barthélemy	17.90	9,885	31.49	33.83	35.40	0	3	3
Saint Lucia	13.89	183,629	32.89	35.04	35.50	0	2	3
Saint Vincent and the Grenadines	13.05	110,947	34.16	35.70	36.57	1	1	1
Saudi Arabia	24.22	34,813,867	27.14	29.36	30.52	62	274	1012
Senegal	14.46	16,743,930	32.36	34.74	35.30	10	38	105
Serbia	44.21	8,737,370	5.37	10.89	7.69	31	135	457
Seychelles	-6.99	98,340	29.60	29.55	30.17	0	6	7
Singapore	1.29	5,850,343	32.70	31.20	30.45	200	385	683
Slovakia	48.67	5,459,643	1.47	6.02	5.27	30	137	226
Slovenia	46.15	2,078,932	3.49	8.97	7.06	141	341	577
Somalia	5.19	15,893,219	35.25	32.83	32.25	0	1	3
South Africa	-34.65	59,308,690	25.75	24.08	22.20	17	205	927
Spain	35.71	46,754,783	11.76	14.11	13.76	4231	19980	56188
Sri Lanka	7.88	21,413,250	34.96	34.68	33.39	6	59	106
Sudan	15.46	43,849,269	32.07	34.70	35.41	1	1	3
Suriname	4.03	586,634	34.72	32.13	31.68	0	2	7
Sweden	55.13	10,099,270	-1.47	0.96	1.91	775	1623	2806
Switzerland	46.81	8,654,618	2.45	7.78	6.21	1125	4840	10714
Syrian Arab Republic	34.81	17,500,657	12.20	14.22	14.36	0	0	5
Thailand	13.04	69,799,978	34.16	35.70	36.57	75	322	1136
Timor-Leste	-8.83	1,318,442	28.10	27.18	28.02	0	1	1
Togo	8.53	8,278,737	34.91	34.83	33.57	1	9	24
Trinidad and Tobago	10.72	1,399,491	34.39	35.11	35.30	1	9	61
Tunisia	34.00	11,818,618	13.46	14.99	15.95	16	54	197
Turkey	39.05	84,339,067	10.40	13.97	12.67	5	670	3629
Turks and Caicos Islands	21.56	38,718	28.73	31.18	32.60	0	0	2
Uganda	1.38	45,741,000	32.70	31.20	30.45	0	0	14
Ukraine	48.28	43733759	1.47	6.02	5.27	3	26	218
United Arab Emirates	24.46	9890400	26.59	28.73	29.86	85	140	333
United Republic of Tanzania	-6.37	59734213	29.64	29.40	30.29	0	6	13
United States of America	37.26	331002647	11.08	13.79	14.42	1678	15219	68334
United States Virgin Islands	18.04	104423	31.49	33.83	35.40	0	3	17
Uruguay	-32.93	3473727	26.28	25.26	21.58	0	94	217
Uzbekistan	41.38	33,469,199	7.93	12.34	9.30	0	33	83
Venezuela (Bolivarian Republic of)	8.28	28,435,943	34.91	34.83	33.57	2	36	91

Viet Nam	15.78	97,338,583	32.24	34.59	35.67	48	91	153
Zambia	-13.1	18,383,956	28.23	26.51	26.80	0	2	3
Zimbabwe	-19.01	14,862,927	29.90	28.86	32.13	0	1	3

Binned Latitude Data		Average Temperature at Latitude			Confirmed Cases near Latitude (+/- 2.5°)		
Study Latitude	**Population**	**14-Mar**	**21-Mar**	**27-Mar**	**14-Mar**	**21-Mar**	**27-Mar**
-42.50	4,822,233	17.0514	15.5040	13.3142	6	53	338
-40.00	50,018,010	20.4288	20.9089	20.0613	40	181	840
-37.50	64,311,986	22.3444	18.9643	18.8127	77	562	1808
-35.00	81,898,626	24.2398	23.6912	21.5318	60	733	2450
-32.50	88,282,298	25.7765	25.7108	22.0398	214	1172	4129
-30.00	27,642,133	27.3579	27.4348	25.4497	197	873	2985
-27.50	2,142,252	31.4486	30.9216	29.4972	0	0	0
-25.00	9,673,446	32.8217	33.1379	32.9120	6	16	49
-22.50	13,205,870	33.8631	33.9473	35.1159	11	46	198
-20.00	77,730,024	32.8355	30.0532	32.9469	6	42	211
-17.50	88,363,554	32.1087	28.8910	32.0003	4	41	187
-15.00	264,765,694	29.4980	28.1486	28.8868	101	656	2611
-12.50	317,307,449	27.3179	26.4357	26.7356	126	861	3068
-10.00	68,726,171	26.8855	26.0163	27.0934	28	235	583
-7.50	70,798,042	30.1384	29.4007	30.0222	0	14	22
-5.00	170,231,765	30.4975	30.0010	30.9690	2	27	75
-2.50	467,097,029	30.9723	29.4500	30.8117	96	774	2243
0.00	451,343,777	32.4381	30.5346	30.5898	491	2179	4923
2.50	88,348,833	33.3472	31.4346	30.8308	438	1532	2901
5.00	132,314,869	34.8597	32.8335	32.2464	59	293	803
7.50	582,610,871	33.5747	34.2346	32.8859	82	575	1836
10.00	495,307,027	32.9475	34.9605	34.7508	74	504	1550
12.50	255,139,532	32.9600	36.0233	36.8464	166	756	2448
15.00	433,224,091	31.2306	34.5190	35.0264	209	830	2438
17.50	354,855,972	31.0251	34.1049	35.5537	69	297	975
20.00	1,535,536,289	29.7731	32.7902	34.3128	121	375	1540
22.50	1,740,442,982	28.2798	30.1638	31.4773	281	860	2781
25.00	455,037,090	25.4406	28.2626	28.9025	742	1603	3388
27.50	229,889,081	22.6477	24.9666	25.8471	700	1332	2303
30.00	1,877,298,984	19.6853	20.8464	22.0935	11620	102632	116586
32.50	2,004,902,031	17.2600	17.7423	18.6180	12395	103734	118214
35.00	682,677,930	13.0539	14.2248	14.3632	15042	46579	140097
37.50	551,236,863	11.8287	13.7874	14.4242	14236	46314	142199
40.00	416,516,360	12.2343	14.1597	12.0144	18059	49687	90711
42.50	330,035,815	9.0442	11.4685	8.2018	18034	48980	87705
45.00	136,111,688	8.4701	10.0423	7.4376	5076	18579	43109
47.50	200,572,748	3.9762	7.2327	5.9971	5685	21890	51254
50.00	238,666,506	1.6644	4.1517	4.2704	5216	27768	66835
52.50	164,827,188	0.2501	2.7511	3.4056	4640	24740	59106
55.00	34,972,115	-2.1001	0.9623	1.9090	1709	3799	7157

57.50	32,845,237	-2.7305	0.5839	2.2285	2536	5535	9884
60.00	12,394,136	-4.9678	-1.0675	0.5952	938	2477	4658

Binned Temperature Data	**Population**			**Confirmed Cases**		
Study Temperature (deg C)	**14-Mar**	**21-Mar**	**27-Mar**	**14-Mar**	**21-Mar**	**27-Mar**
-10	341,250	0	0	109	0	0
-7.5	390,115	0	0	1,755	0	0
-5	14,280,338	390,115	341,250	2,538	2,588	0
-2.5	47,317,386	5,987,605	390,115	5,421	28,018	964
0	194,775,910	47,317,386	32,979,134	4,712	28,591	11,815
2.5	264,331,866	203,409,893	209,007,383	5,480	6,026	70,088
5	189,237,790	238,666,506	365,314,904	5,529	20,986	66,835
7.5	114,436,312	189,237,790	290,372,917	493	19,571	49,192
10	880,065,317	213,396,408	330,035,815	32,243	95,227	47,029
12.5	928,505,345	956,345,736	797,638,208	32,891	94,085	230,554
15	327,034,606	1,021,909,570	626,309,921	12,374	1,931	226,888
17.5	1,929,828,973	1,728,052,851	332,265,030	11,629	104,055	117,813
20	1,817,182,200	1,836,534,794	2,061,745,609	239	102,924	118,149
22.5	355,450,930	445,159,615	1,882,870,790	395	1,811	3,618
25	655,222,874	416,072,883	349,466,750	926	2,723	5,853
27.5	2,194,229,049	1,367,421,458	492,207,254	868	2,468	12,072
30	2,587,440,366	2,672,284,831	1,355,931,485	820	4,627	11,603
32.5	1,817,938,005	2,518,792,696	3,046,242,779	715	4,034	7,021
35	986,847,330	1,205,855,488	2,530,303,113	306	471	5,427
37.5	0	238,020,337	601,433,505	149	0	2,277